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ABSTRACT

The document is an instructor's guide for a course on universal tool grinder operation. The course is designed to train people in making complicated machine setups and precision in the grinding operations and, although intended primarily for adult learners, it can be adapted for high school use. The guide is divided into three parts: (1) the introduction (four pages) presents the objectives of the course and discusses its related aspects: units of measurement, metric units, drawings and job sheets, assignment of work to students, and administration of the course; (2) the general job content section (10 pages) presents teaching points and techniques for the following areas: types of machines, machine parts, machine accessories, cutting tools, measurement and inspection, blueprint reading, speed and feeds, trade mathematics, coolants, care and maintenance, safety, trade terms, and operations; (3) the section on job sheets for shop projects (47 pages) presents separately 28 projects and 39 related shop jobs with information on the following: time required, performance objectives, operations, equipment, materials, selected references, a list of procedures and techniques, and related information. A bibliography and 12 drawings for shop projects are included. (EC)

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Machine Industries Occupations

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INSTRUCTOR'S GUIDE

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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UNIVERSAL TOOL GRINDER OPERATOR

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PART OF SINGLE-TOOL SKILLS PROGRAM SERIES

THE UNIVERSITY OF THE STATE OF NEW YORK / THE STATE EDUCATION DEPARTMENT
BUREAU OF CONTINUING EDUCATION CURRICULUM DEVELOPMENT
BUREAU OF SECONDARY CURRICULUM DEVELOPMENT / ALBANY NEW YORK 12234

Universal Tool Grinder Operator

INSTRUCTOR'S GUIDE

Part of
SINGLE-TOOL SKILLS PROGRAM
MACHINE INDUSTRIES OCCUPATIONS

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of Continuing Education Curriculum Development
Bureau of Secondary Curriculum Development
Albany, New York 12234
1975

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Foreword

The *Universal Tool Grinder Operator* course contained in this book is intended to help fill the need for people trained to operate machine tools. This course is the fifth one to be published in a series of instructors' guides for the Single-Tool Skills Program.

The courses already published in the Single-Tool Skills Program are *Engine Lathe Operator* in 1972, *Surface Grinder Operator* in 1973, *Milling Machine Operator* in 1974, and *Drill Press Operator* in 1975. *Universal Tool Grinder Operator* was produced as a joint project of the two curriculum bureaus named on the title page. This course is primarily an adult course but some of it can be adapted for use in a high school course.

The Single-Tool Skills Program is one of the programs in a broad plan covering machine industries occupations. The original plan was conceived by Robert S. Hunter, former associate in the Bureau of Trade and Technical Education of the State Education Department. A number of teachers were involved in the overall planning for machine industries occupations and also wrote materials for the course guides. They are Elek D. Csont, Seneca Vocational High School, Buffalo; Jack Grossman, Alexander Hamilton High School, Brooklyn; Alfred Kagan, Sewanhaka High School, Floral Park; Gilbert Pultz, Jefferson Vocational and Technical Center, Watertown; William G. Stewart, North Senior High School, Binghamton; William F. Tiedemann, Central Technical High School, Syracuse; and Joseph Waldinsperger, College of Continuing Education, Rochester Institute of Technology, Rochester.

Some members of the State Education Department took part in the overall planning and in the further detailed planning which resulted in the production of this publication. They are E. Noah Gould, associate in the Bureau of Occupational and Career Curriculum; G. Earl Hay, chief of that bureau; Edward Shattuck, former associate in the Bureau of Trade and Technical Education; and Charles A. Stebbins, associate in the last-named bureau.

Messrs. Kagan, Stewart, and Tiedemann wrote the *Universal Tool Grinder Operator* course contained in this book. Most of the drawings in this guide are taken from previous publications in the series. The additional drawings and changes in old drawings were made by Eugene F. Stalica, Jr., professor at Hudson Valley Community College, Troy. Mr. Gould, who is in general charge of the Single-Tool Skills series, directly supervised the writing and edited the manuscript.

G. EARL HAY, *Chief*
Bureau of Occupational and Career Curriculum

GORDON E. VAN HOOFT, *Director*
Division of Curriculum Development

Message to the Instructor

The *Universal Tool Grinder Operator* course contained in this book requires the trainee to make complicated machine setups and to use considerable precision in the grinding operations. Great manual dexterity is needed to achieve the proper cutting edge angles and clearance angles. This level of skill and the machine trades knowledge associated with it come only after much experience.

Among those who enter the courses covered by the guides published previously in this series, a broad range of backgrounds can be expected. However, the complexity of the course covered in this book requires trainees who have completed the engine lathe and milling machine courses, or equivalent courses.

Anyone who completes this course successfully will be qualified for an entry-level job as operator of a universal tool grinder. Some students may also complete other single-tool courses and qualify to operate more than one machine tool. It is even possible that a student with outstanding ability, by completing the courses for several machine tools, could become a machinist.

The 28 projects in this course (which include 39 shop jobs) are listed on the page after *Contents*. There is no requirement that any student complete all projects, or even all jobs within any project. The instructor may determine which projects and jobs students should complete and whether to have them use conventional or metric dimensions. The instructor may also use other jobs not included in this book.

The instructor for this course would ideally be a person with not only good training and experience in machinist skills, but also several years of teaching experience. The best sources from which to draw teachers are the faculties of schools giving machine tool courses and the ranks of those employed as machinists and supervisors of machinists.

An administrator or instructor who has any questions or comments about this publication should direct them to either the Bureau of Trade and Technical Education or to one of the bureaus named on the title page.

CARL G. BENENATI, *Chief*
Bureau of Trade and
Technical Education

Douglas T. Adamson, *Director*
Division of Occupational Education Instruction

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MACHINE INDUSTRIES OCCUPATIONS
SINGLE-TOOL SKILLS PROGRAM
UNIVERSAL TOOL GRINDER OPERATOR COURSE

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MACHINE INDUSTRIES OCCUPATIONS
SINGLE-TOOL SKILLS PROGRAM
UNIVERSAL TOOL GRINDER OPERATOR

LIST OF DRAWINGS FOR SHOP PROJECTS

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30.1**	Arbor Press Sleeve (Dual Dimensioning)	XXVI	1A,1B	109
34A	Lathe Mandrel (Inches)	XXII	1A	110
34B	Lathe Mandrel (Millimeters)	XXII	1B	111
50A	Parallels (Inches)	XXI	1A	112
50B	Parallels (Millimeters)	XXI	1B	113
73	Lathe Forming Tool for Die Wrench Handle	XX	1	114
74	Taper Plug Gage (Dual Dimensioning)	XXV	1A,1B	115
75	Taper Ring Gage (Dual Dimensioning)	XXVIII	1A,1B	116

* The micrometer boring head dial is only one part of an assembly. Machining operations on other parts of the assembly are included as shop projects in other teachers' guides in the Single-Tool Skills series. The assembly drawing and drawings for all other parts in the assembly appear in the following three guides:

Drill Press Operator,
Milling Machine Operator,
Surface Grinder Operator.

The guide *Engine Lathe Operator* contains the assembly drawing and drawings of *some* of the other parts.

** In the same way as described in the note above, the arbor press sleeve is only one part of an assembly. The assembly drawing and the drawings of all other parts in that assembly appear in all four of the publications mentioned in that note.

Introduction

As shown in the contents, this *Universal Tool Grinder Operator* course consists of this Introduction, General Job Content (which explains what the operator's job includes), Job Sheets for projects, photographs of setups (on some of the Job Sheets), and drawings for the projects which need them. The course covers the operation of the universal tool grinder only.

Objectives of the Course

The job for which the trainee would be qualified upon completion of this course is referred to in the Dictionary of Occupational Titles (under the code number 603.280) as grinder operator, universal, tool; precision grinder, universal; and universal grinder, tool. Other related job titles are also used under this and other code numbers.

The general objective of the course is to qualify a person, in a comparatively short time, for a job operating and setting up a universal tool grinder. The course is intended primarily to provide the skill to operate one kind of metalworking machine, but in this case a broader background in metalworking is provided than in other courses in the series. But the training time is still kept to a minimum, and the trainees are made available for work without a long delay.

Units of Measurement

Generally speaking, conventional units of measurement (inches for linear dimensions, and degrees for angles) are used in this course. However, the student is introduced to metric measurement by use of millimeters for dimensions in seven shop jobs, in addition to the conventional units.

The United States is the last major industrial country which has not adopted metric measurements generally. But the much greater convenience of metric units and our increasing trade with countries on the metric system are rapidly pushing us toward metrication. Within a few years it is very likely that metric units will become our predominant means of measurement.

In American industry, some companies are already using metric measurements to a large extent in their products. Examples of such companies are the Beloit Tool Corporation of South Beloit, Illinois, and the Caterpillar Tractor Company of Peoria, Illinois. But American metalworking companies using metric units are apparently continuing to use conventional thread systems. This is because, according to some authorities, the conventional threads have some significant advantages over metric threads. References listed in the bibliography contain further information on metrics.

Metric Units in this Course

In this course, the workpieces for seven shop jobs have been designed in both conventional and metric units. Job Sheets and drawings using both

inches and millimeters are included so an instructor can have a student make these pieces in either conventional or metric dimensions or both. The types of project and the number of each project in which these jobs are included are as follows:

Surface Grinding:	Project XXI
External Cylindrical Grinding:	Project XXII
	Project XXIII
	Project XXIV
	Project XXV
Internal Cylindrical Grinding:	Project XXVI
	Project XXVIII

In metric jobs, a 150mm metric scale, a 0.25mm micrometer, and a metric dial indicator are usually needed.

Drawings and Job Sheets

The drawings in this course are part of a serially numbered set beginning with No. 1, which appears in the *Engine Lathe Operator* course. The numbers continue through the drawings of other courses in the Single-Tool Skills Series including this one. They will be continued further in any other courses in the series which might be published later. Drawings in this course which are also in one of the other courses are reproduced here with the same drawing numbers. Some drawings in this book are related to drawings in other books in the series. This is explained on page viii.

In the drawings, all dimensions are in inches unless otherwise indicated. Two of the drawings contain tables giving several different sets of dimensions for the workpieces pictured. These tables permit the instructor to select the set of dimensions best for each student or for the conditions under which the class operates.

Each Job Sheet has the words *Unit No.* in the upper left corner, but no number is given. Instructors may wish to write a number in this space to fit in with their own method of organizing classroom and shop work.

Assignment of Work to Students

As a shop project is assigned to a student, we recommend that the instructor provide copies of the applicable Job Sheets and drawings. The binding of this book permits easy removal of pages for copying. When copies are made, the pages themselves must be kept clean and should not be used by anyone working on a machine. After copies are made, the pages should be replaced in the book and the book should be kept in a looseleaf cover.

Each drawing has four blocks for information at the bottom and in most cases one at the right is blank. We suggest that the instructor have the students write the numbers of the project and job for which they are using the drawing in this blank space on their own copy. If the block is not blank the students can write the numbers just above the block.

Many of the workpieces on which grinding is to be done in this course are those produced in other courses in the Single-Tool Skills series. If a given workpiece is not available as the output of another course in the shop, it is the instructor's responsibility to obtain the workpiece. In some cases, the instructor may need to make the needed part.

Administration of the Course

We believe that enough general information about the job and more than enough shop projects are included for the trainee to reach the general objective of the course. All essential skills are used in the shop jobs a number of times.

The schools may use everything in the course, they may select only some of the material, they may make changes in it, and they may use other material not contained here. They may also determine the length of the class periods, their frequency, and the total amount of time to be spent in training. For those that need a guide: A typical adult night class runs $2\frac{1}{2}$ to 3 hours, either once or twice a week, for 30 weeks.

The prerequisites for admission to an adult course should be broad enough so none will be barred who could be made employable. The operating authorities for each program, school, and school district have the responsibility for determining the prerequisites for such a course, and can adapt them to any special local condition.

The *minimum* prerequisites we suggest for the courses in this series generally are that the trainee be able to understand and follow the course instructions (both written and oral) to produce the simplest workpiece included in a course. For the *Universal Tool Grinder* course, however, greater prerequisitie skill is needed, and suggested prerequisites are shown in the Foreword.

Each Job Sheet shows at least one reference especially recommended for universal tool grinder work. The bibliography gives the complete citations for all references on the Job Sheets and also contains additional references.

Abbreviations used in this course are given on the next page.

Abbreviations Used in Text and Drawings

ALUM.	aluminu	LG.	long
ASSY.	assembl	LGTH.	length
CBORE.	counterbore	MATL.	material
CHAM.	chamfer	MED.	medium
CM	centimeters	MM	millimeters
CRS	cold rolled steel	PT.	part
CSK.	countersink	R or RAD.	radius
DIA.	diameter	REQD.	required
DP.	deep	R.H.	right-hand
DP	diametral pitch	SCR.	screw
DR.	drill	SOC.	socket
DR or DR. ROD	drill rod	SPEC.	specifications
EQ. SP.	equally spaced	SPHER.	spherical
FAO	finish all over	SQ.	square
HD	head	STL.	steel
HDL.	handle	T.P.F.	taper per foot
HEX.	hexagonal	T.P.I.	taper per inch
HGT.	height	TYP.	typical
H.S.	high-speed	W.	width
HT.	height		

General Job Content

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
I.	Types of Machines	Introduce the various kinds of cutter grinders that are available to sharpen cutting tools: 1. universal cutter and tool grinder 2. cutter and tool grinder 3. monoset cutter grinder 4. drill sharpening grinder Explain that some cutter grinders utilize electro-machining principles in the sharpening of cutters, especially those made of carbide.
II.	Machine Parts	Differentiate among the kinds of spindles, such as cartridge and solid bronze. Proceed by showing that the abrasive wheelhead is offset on some machines and that both the main column and the wheelhead can be swiveled in a 360° arc for greater range in work size. Mention the fact that some cutter grinders are designed with a tilt grinding wheelhead which eliminates the need for lowering the tooth rest below center for cutter-clearance angles. Point out the purposes of the double-end spindle grinding wheelhead such as: right- and left-hand operations, and internal grinding operations. Show that the wheelhead can be raised or lowered to establish cutter-clearance angles, and obtain clearance for the cutter wheel. State that some types of cutter grinders are provided with power feeds, particularly when the machine is equipped with a cylindrical grinding attachment. Cite the fact that machines used for cutter grinding alone are generally equipped with a hand feed which has both fine and rapid adjustments. Call attention to other parts of the machine and their functions, such as: the table, the swivel table, the stops, the locking clamps, etc. Mention that the lead screw dials have different graduations, such as: .0001", .001", and .0005". Add the fact that the grinding wheelhead swivel is graduated in degrees, and that some are equipped with a vernier.

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
III.	Machine Accessories A. Work holding	Mention that there are accessories available for cutter grinders, such as: 1. gear cutter sharpening attachment 2. surface grinding attachment 3. cylindrical grinding attachment 4. radius grinding attachment Draw attention to such work holding devices as collets and tapered sleeves. Discuss the value of other work holding devices available for tool grinding. For example: tilting table attachment and universal work head.
	B. Toolholding	Explain that there are interchangeable wheel adapters for the various operations. These include the extended grinding wheel spindle and the internal grinding wheel quills of different lengths.
	C. Other	Tell about the use of such accessories as: 1. spray mist coolant 2. flood coolant system 3. exhaust attachment 4. radial diamond dressing attachment
IV.	Cutting Tools	Point out some of the grinding wheel abrasives, such as diamond, aluminum oxide, and silicon carbide. Explain the standard grinding wheel coding system for grade, bond, etc. State that there are standard types of grinding wheel shape. Two examples are Type 7, which is recessed on two sides, and Type 1, which is a straight or plain type of wheel. Explain further than any standard formed wheel face is available in the straight wheel type. An example is Type D with a 60° angle tangent to a radius. Relate the types of wheels mentioned above to their applications, for example, form grinding a concave turning tool. Give a demonstration of the proper procedure for mounting a grinding wheel. Discuss methods of dressing the grinding wheel. Some of these could use: silicon carbide sticks, diamond dresser, and crush dressing. Explain the principle of crush wheel dressing when applied to form grinding. Elaborate on some related items such as: 1. crush wheel size and composition

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
		2. grinding wheel types 3. speeds and feeds for crushing or grinding State the importance of truing a diamond grinding wheel using an indicator. Use the manufacturer's recommendations and specifications. Illustrate by the use of diagrams or pictures how various dressing tools should be applied to the diamond grinding wheel. Furnish grinding wheel section charts and show how they are used in the selection of a grinding wheel for a particular problem. Interpret *diamond wheel concentration*. For example: When used for offhand grinding, wheels of "50" concentration are recommended for both vitrified and metal-bonded cup wheels. These should be combined with a hard grade for lower grinding costs. Explain the maeaning of diamond wheel terms such as: 1. concentration 2. bond 3. grit size
V.	Measurement and Inspection	List and explain the types of measuring tools. These could include the micrometer, the comparator, and the cutter-clearance gage. Introduce the use of gage blocks, sine bar, height gage, and indicator for the inspection of angles. An example is the sharpening of tapered reamers.
VI.	Blueprint Reading	Introduce and cover all necessary blueprint reading, including: 1. theory of orthographic projection 2. language of lines 3. sectional views 4. tolerances 5. finishing symbols
VII.	Speed and Feeds	Discuss the meaning of surface speeds in relation to type and size of wheel. Correlate the depth of cut to be taken when sharpening cutters, to the type and kind of grinding wheel being used and the material being ground.

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
		Continue by explaining how longitudinal and/or rotary work speeds will affect wheel wear and surface finish. Call attention to the fact that the area of contact on the wheel cutter teeth affects the heat buildup, which could take the temper out of the cutting edge. Explain that cutter sharpening can be done by two methods: with the wheel revolving toward the cutting edge and with the wheel revolving away from the cutting edge.
VIII.	Trade Mathematics	Introduce and cover all the trade mathematics necessary, including: surface speed formulas, r/min formulas, and trigonometric functions.
IX.	Coolants	Present information about the use and kinds of cutting fluids, such as soluble oils and wax-type lubricants. Explain the desired characteristics of the cutting fluids to achieve high cutting speed, good surface finish, and economic tool life. Mention the three functions of cutting fluids: as a lubricant, as a coolant, and as an antiwelding agent. Demonstrate where the coolant flow should be directed in relation to the work and the grinding wheel. Explain that dirty coolant will affect the surface finish by leaving scratch marks. Discuss the ratio of water to concentrate for mixing water type coolants. Point out that there is a spray mist system of applying coolant in addition to the flood method. State that most cutter grinding is done dry. But there are instances where cutter sharpening is done with the aid of a fluid. For example: When sharpening cutters with the use of an electrochemical cutter grinder, a saline solution is used for a flush, and an electrolyte is also used.
X.	Care and Maintenance	Provide information about the maintenance of the cutter grinder in use. This can include cleaning of machine, care and cleaning of accessories, and mounting of wheel sleeves.

CONTENT OUTLINE		TEACHING POINTS AND TECHNIQUES
		Utilize the standard operation and repair manual for additional information concerning the type of grinder in use. Mention the procedure for reconditioning work centers and checking for accuracy with a center gage. Emphasize the importance of keeping all tools and accessories clean, properly stored, and in good condition.
XI.	Safety	Introduce the following safety rules that must be followed when operating any machine. 1. Wear safety glasses and close fitting clothes. 2. Make sure machine guards are in place. 3. Keep hands away from moving parts. 4. Know how to operate the controls. Discuss ways of avoiding the particular dangers of the cutter grinder: 1. Inspect all wheels before mounting. 2. Always use wheel blotters and correct flanges to mount a grinding wheel. 3. Do not force a grinding wheel on to a spindle. It should fit freely. 4. Do not tighten the grinding wheel with too much force. 5. Move the workpiece to the wheel very cautiously when grinding. 6. Avoid standing in line with the plane of the wheel when starting the grinder. 7. Never remove or insert work while a grinding wheel is running. 8. Use dust collecting devices for dry grinding. 9. Handle all cutters with extreme care. 10. Put all feed levers in neutral position when you are using a machine.
XII.	Trade Terms	Explain all terms which are pertinent to this unit of the course. An example is *land*, which is the back width of the cutting edge of the tooth.
XIII.	Operations	
	A. Sharpening	Demonstrate how to set the wheelhead in relation to the operation to be performed. Explain how the wheelhead can be lowered or raised for centering the wheel with relation to the work center, or for obtaining cutter tooth clearance angles. Illustrate to the group how the centering gage is used to check cutter tooth height in relation to grinding wheel height.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	Describe the procedure for sharpening a plain milling cutter with helical or straight teeth. For example: Use an offset tooth rest with a radius end for helical milling cutters, and a straight spring back rest for a straight toothed milling cutter. Mention further that primary and secondary angles can be obtained by rotating the cutter, using the degree gage calibration on the clearance-setting dial. Explain that the cutter may be pressed on an arbor, or slide, or an arbor set between work centers. For example: Helical cutters are generally set to slide along the finger rest, and straight tooth cutters are rotated against a springaway finger set. Point out that a cup wheel is generally used in this operation but a plain grinding wheel can be used. Explain that the size of the clearance angles on a cutter are based on the diameter of the cutter and the materials to be milled.
B. Face milling, double and single side milling cutters	Demonstrate how to set up a face milling cutter for sharpening, using a workhead or a face mill grinding attachment. Point out the use of the offset tooth rest and how it is attached to the table. Show how the chamfering of corners can be accomplished by swiveling and tilting the workhead to the desired angle. When chamfering, you should use a straight finger with a rounded tip set under the face of the tooth to be ground. It should be attached to the table. Call attention to the procedure for grinding the face of the cutter with a straight finger having a rounded tip attached to the wheelhead.
C. Staggered tooth side milling cutters	A special tooth rest blade must be ground to coincide with the right and left-hand angle of the milling cutter tooth. This is done to maintain original cutter tooth angle. The tooth rest angle lengths must be wide enough to project beyond the sides of the wheel. This will prevent the cutter sliding off the end of the tooth rest before completion of grinding wheel contact.

CONTENT OUTLINE	TEACHING INFORMATION AND TECHNIQUES
	Suggest that the cutter be mounted on a mandrel or arbor between work centers, and that the finger be mounted on the wheelhead. State that the side teeth are not to be sharpened except in cases of extreme necessity. Explain that sharpening them would alter the width of the cutter and would affect the width of a milled slot.
D. Sharpening shell end-mill	Note that these cutters are sharpened with the same procedures used for sharpening face and plain milling cutters. Caution the students that the wheelhead in many cases, must be lowered so the grinding wheel will not contact the cutter tooth above the one being ground. Show how face tooth secondary clearance is obtained by lowering the tooth rest and tilting the work head.
E. Sharpening end mills	Utilize the motor-driven workhead to grind away the damaged area of the end mill, using a resinoid cutoff wheel on the left-hand spindle. Proceed by showing how to hollow grind the face of an end mill, using a workhead and a small diameter wheel. Show how cutter clearance is obtained on the end teeth when using a cup wheel and a workhead. It is done by setting the tooth rest on the table and bringing it up under the peripheral tooth. Call attention to the use of the centers for grinding primary and secondary clearance on the peripheral teeth of end mills with centerholes.
F. Sharpening small end mills	Introduce the use of the small end mill grinding attachment and the air flow fixture.
G. Sharpening spot-facing tools	State that spot-facing tools are sharpened by the use of the workhead to hold the cutter. A cup wheel is used for the grinding in this case.
H. Sharpening slotting cutters	Mention that slotting cutters are sharpened singly or can be ground in groups mounted on an arbor for production purposes.

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	Show how the tooth rest is set and how to regulate for primary and secondary clearances. Follow the same tooth rest procedure as for a straight plain milling cutter.
I. Sharpening angular cutters	Describe the setting up of the workhead and the tooth rest to sharpen the face and angular teeth.
J. Sharpening T-slot cutters	Describe the procedures necessary to grind straight or staggered tooth T-slot cutters.
K. Sharpening reamers	Warn that sharpening of reamers requires the greatest accuracy necessary in tool and cutter grinding. Slight inaccuracies in the sharpening of a reamer will result in an improperly working tool and faulty workmanship.
	Point out that it is best to use a micrometer tooth rest to eliminate the possiblity of error.
	Stipulate that its shape and taper must be maintained. This is accomplished by various machine adjustments.
L. Sharpening cemented carbide	Stress the fact that grinding wheel selection is important in the grinding of carbide tools because they are very hard but low in tensile strength. They lack ductility, have low heat conductivity, tend to crumble at the cutting edge, and check during grinding.
	Point out that silicon carbide wheels are used if a tool is badly chipped or excessive material must be removed prior to finish grinding with a diamond wheel.
M. Sharpening fly cutters	Call attention to the methods of sharpening fly cutters. For example: holding between work centers for grinding the periphery with a cup wheel.
	Continue by showing how to grind the face of the cutter tooth with a Type 12 dish wheel.
N. Sharpening radius cutters	Show how a radius grinding attachment is set up on the worktable and how to set the attachment to obtain a given radius.
	Mention how the grinding wheel is dressed to a

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	given concave, convex, or angular form, using a radial diamond dressing attachment.
O. Sharpening gear cutters, etc.	Explain that the following cutters are sharpened on a universal tool grinder: 1. spur gear cutters 2. hobs 3. form-relieved cutters 4. involute gear cutters Stress the fact that form cutters are ground radially on the face so the form is not changed. Note that the face is tipped forward of center so that when this surface is ground it will run through dead center.
P. Sharpening special cutters	Emphasize that all cutters mentioned above may be converted to special shapes wherever convenient.
Q. Lathe tools	Call attention to the use of the universal vise for obtaining clearance and rake angles.
R. Taps	Discuss the sharpening of taps using a tap grinding attachment. Include: squaring the ends, grinding relief, and sharpening flutes.
S. Chasers	Mention that chasers can be ground using a universal clamping device and a plain grinding wheel.
T. Sharpening drills	Call attention to the fact that drill sharpening operations such as web thinning, split pointing, and step drill sharpening can be done with cutter grinders.
U. Surface grinding	State that surface grinding is sometimes done by mounting a magnetic chuck and/or vise machine table, and using an extension arbor.
V. Cylindrical grinding	Explain that cylindrical grinding is often done on the universal tool grinder. Some of the operations performed might be: straight grinding, plunge grinding, shoulder grinding, and taper grinding. Show how to set up workhead and footstock centers, and aline work and table with an indicator. Illustrate the use of a steady rest for grinding slender workpieces.
W. Internal grinding	Discuss the operations and the related setups with an internal grinding attachment, to obtain: straight

CONTENT OUTLINE	TEACHING POINTS AND TECHNIQUES
	holes, tapered holes, and shouldered holes. Furnish information as to wheel size in relation to the hole to be ground. Call attention to the following problems or causes of problems which can occur in grinding: 1. bell-mouthed hole 2. spring of the quill 3. tapering of hole 4. improper wheel speed

Job Sheets for Shop Projects

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project I *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Plain Milling Cutter (Straight Teeth) *D.O.T. No.* 603.280

Time: 3 hours

Performance Objectives:

Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:

1. Wheel dressing
2. Straight grinding

Materials:

Plain milling cutter with straight teeth

Equipment:

Tool and cutter grinder	Work centers
Grinding wheel	Tooth rest
Wheel dresser	Mandrel
Clearance-setting dial	Cutter-clearance gage
Clearance-setting dog	Centering gage
Footstock centers	

Selected references:

McCarthy & Smith. *Machine tool technology;* 3d edition

Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 89° and attach cup wheel Type No. 11. See Fig. 1-1.	1. Use recommended wheel from manufacturer's charts.
2. Dress wheel sharp and true.	2. Follow shop practice.
3. Mount footstocks with centers on machine table.	3. Check alinement of machine table to assure straight grinding on cutter teeth.
4. Attach clearance-setting dial to left-hand footstock.	
5. Attach micrometer tooth rest to table and center the blade with centering gage.	5. Review types of tooth rests and the use of the centering gage.
6. Place the cutter on a mandrel and mount it between centers in footstocks.	
7. Place the tooth to be ground on the tooth rest; clamp the mandrel to the clearance setting dial set at 0, Fig. 1-2.	7. Review use of clearance-setting dial.
8. Lower the tooth rest and rotate the cutter to the desired clearance angle on the clearance-setting dial.	8. Refer to chart of cutter-clearance angles. Be sure tooth rest supports the tooth at the correct angular setting.
9. Remove the clamp dog from the mandrel, hold the tooth of the cutter firmly	9. Make a spark contact only; do not take a heavy cut.

PROCEDURE	TECHNIQUES AND RELATED INFO.
against the tooth rest, and move the table in to contact the tooth with the grinding wheel.	
10. Move the tooth surface across the face of the grinding wheel and return. Index to next tooth and move it across and return. Repeat for all teeth.	10. Mark starting point with layout dye.
11. After going around all teeth at the contact setting, continue grinding until desired sharpness is developed.	11. Review requirements for correctly sharpened cutters. Finish with light cut and fine feed.
12. After primary clearance has been completed, lower the tooth rest further, clamp the mandrel to the clearance setting dial, and rotate the cutter to the desired angle. Lock it in place and bring the tooth rest up against the tooth.	12. Consult chart for recommended secondary clearance angle.
13. Contact the wheel and grind each tooth at contact setting.	
14. Continue grinding each tooth in turn until the required land is established.	14. See manufacturer's literature for standards for width of land.
15. Remove mandrel from centers. Remove cutter from mandrel and submit it for inspection and grade.	15. Caution: Handle sharp cutters with care.

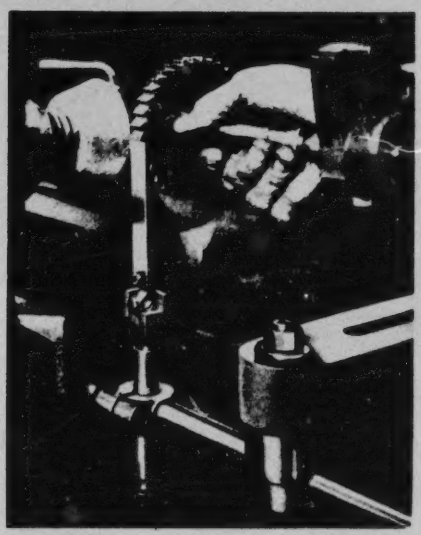

Figure 1-1

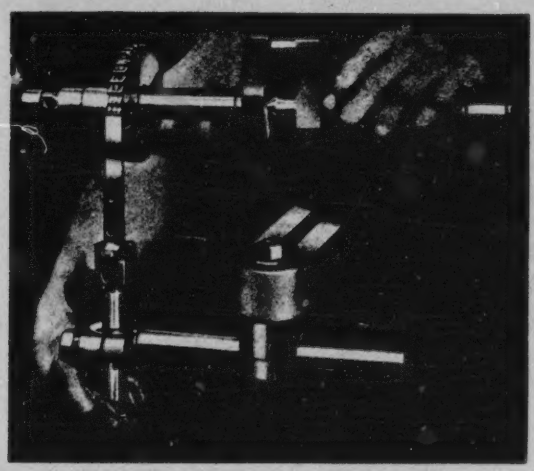

Figure 1-2

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project II *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Plain Milling Cutter (Helical Teeth) *D.O.T. No.* 603.280

Time: 4 hours

Performance Objectives:

Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:

1. Wheel dressing
2. Grinding helical teeth

Materials:

Plain milling cutter with helical teeth

Equipment:

Tool and cutter grinder	Work centers
Grinding wheel	Tooth rest
Wheel dresser	Mandrel
Clearance-setting dial	Cutter-clearance gage
Clearance-setting dog	Centering gage

Selected references:

McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 89° and attach cup wheel Type No. 11. Dress the wheel.	
2. Center the wheelhead spindle using the center gage on the table. See Fig. 2-1.	2. Review use of center gage.
3. Attach plain tooth rest with offset rounded head blade to the wheelhead with the head of the blade in front of the edge of the cup wheel. See Fig. 2-2.	3. Review types of tooth rests and blades.
4. Mount footstocks on table with centers in place and table travel straight.	4. Check with indicator mounted on wheelhead for precise straight travel.
5. Mount cutter on mandrel and locate between centers in footstocks.	
6. With centering gage on top of wheelhead, rotate cutter to bring the end of the first tooth to be ground against the gage block of the centering gage.	6. This is the starting point of contact with the helical tooth.
7. Holding the cutter precisely in this position, clamp the mandrel to the clearance-setting dial with the dial set at 0. See Fig. 2-3.	7. At this point, the end of the first tooth, the centerline of the cutter, and the centerline of the grinding wheel are in alinement.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Remove the centering gage and rotate the cutter, mandrel, and clearance-setting dial to the desired clearance angle; clamp securely.	8. Consult a chart for correct clearance angle.
9. Move the cutter in until it almost contacts the grinding wheel. Then adjust the offset tooth rest blade firmly against the tooth to be ground and lock it in place.	9. Do not rotate the cutter while adjusting the tooth rest.
10. Remove the clamp from the mandrel and traverse the table back and forth. At the same time rotate the cutter by hand to keep the spiral tooth firmly against the tooth rest at all times. See Fig. 2-4.	10. Do this without wheel contact to be sure of smooth operation without interference.
11. Contact the first tooth with the grinding wheel and grind full length and return. Do this while holding the mandrel in one hand to maintain constant contact with the tooth rest.	11. Clamp cylindrical grinder driving dog to the mandrel for a better way to hand rotate the cutter on the return pass.
12. Grind all teeth on the contact setting and check the diameter for taper with a micrometer. Adjust the table if there is any taper.	12. Cutter must be ground straight with no taper.
13. Finish grinding the primary clearance angle until all teeth are sharp. Finish with fine cut on all teeth.	13. Check angle with gage.
14. Grind the secondary clearance angle in the same way except with a larger angular setting. Repeat the setup procedure and readjust the tooth rest. Grind to required land.	14. Use a chart to find correct secondary angle and width of land.
15. Submit the cutter for inspection and grade.	

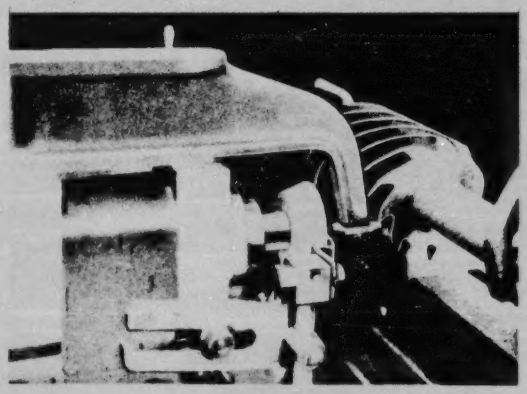

Figure 2-1

(Photos on this page and page 20 by courtesy of Clausing Corp.)

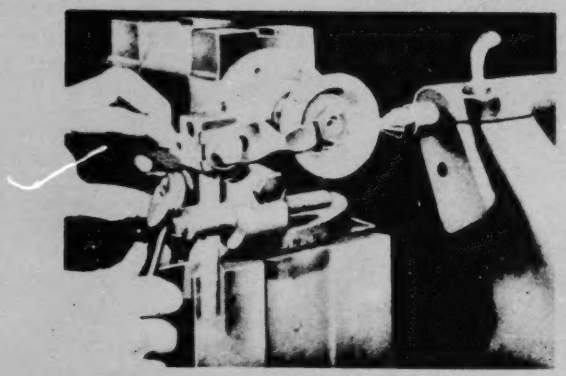

Figure 2-2

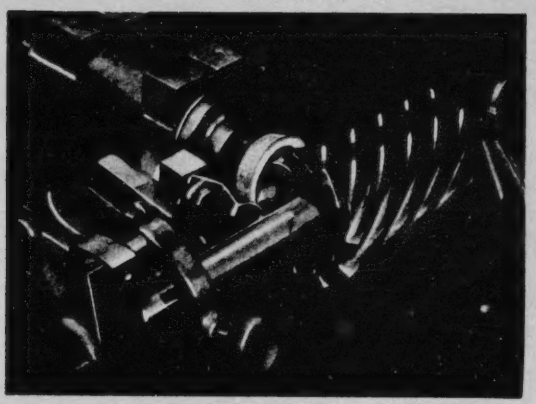

Figure 2-3

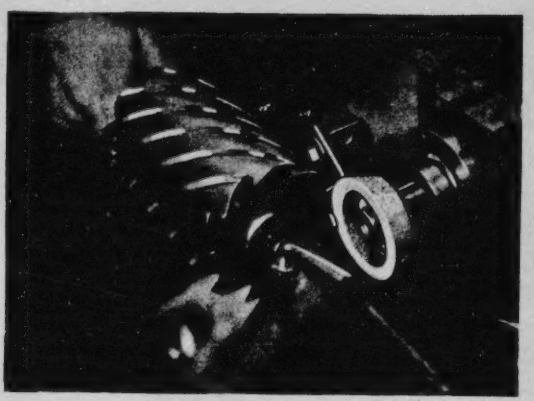

Figure 2-4

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project III *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Side Milling Cutter (Straight Teeth) *D.O.T. No.* 603.280

Time: 5 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding peripheral teeth
3. Grinding side teeth

Materials:
Side milling cutter with straight teeth

Equipment:

Tool and cutter grinder	Tooth rest
Grinding wheel	Universal workhead
Wheel dresser	Mandrel
Footstock centers	Arbor
Clearance-setting dial	Cutter-clearance gage
Clearance-setting dog	

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 89° and attach cup wheel Type No. 11.	
2. Dress wheel sharp and true.	
3. Mount footstocks with centers on table.	
4. Set table at 0 for straight grinding.	4. Indicate straight.
5. Attach micrometer tooth rest to work table and adjust to center height with centering gage.	5. Use center gage on table surface to locate tooth rest height.
6. Place cutter on a mandrel and locate between footstock centers.	
7. Place tooth to be ground on the tooth rest and clamp the mandrel to the clearance-setting dial. Set dial at 0. See Fig. 3-1.	
8. Lower the tooth rest and rotate the cutter to the required angle for primary clearance. Adjust the tooth rest to firm contact with tooth at this angle.	8. Consult chart for required angle.
9. Remove the clamp dog. With the tooth against the tooth rest, contact the grinding wheel for a light cut.	9. Mark starting tooth with layout dye.

PROCEDURE	TECHNIQUES AND RELATED INFO.
10. Grind all teeth at the contact setting, holding each tooth firmly against the rest.	
11. Continue grinding until all teeth are sharpened; finish with light cuts.	11. Variations in cutting condition before sharpening must be dealt with.
12. Check the width of land and grind secondary clearance as needed.	12. Check angles with cutter clearance gage.
13. Lower the tooth rest further, attach the clamp to the mandrel, and rotate the cutter to the desired secondary clearance angle.	13. Refer to chart for recommended secondary angle.
14. Set the tooth rest to the tooth at this angle and remove the clamp from the mandrel.	
15. Grind all teeth to the required width of land.	
16. Remove cutter from mandrel and stone edges slightly.	16. CAUTION: Handle sharp cutters with extreme care.
17. Locate the universal workhead on the table, swivel the base $\frac{1}{2}°$ to the right and tilt it down $3\frac{1}{2}°$. These settings are with the table set at 0.	17. Review machine attachments and setups.
18. Attach the side cutter to a stub arbor and mount in workhead.	18. Review the principles of taper fits and use of a drawbar for holding the milling machine taper.
19. Attach the micrometer tooth rest to the table and center the blade height under the tooth to be ground. Use the centering gage mounted on the table.	19. Tooth rest blade is located on peripheral tooth for sharpening the side of the tooth. See Fig. 3-2.
20. Lower the wheelhead until the cup wheel will clear the next tooth above the tooth being ground.	20. Review the sizes of cup wheels.
21. Mark the tooth with layout dye and proceed to grind the side teeth on the primary angle.	
22. Lower the tooth rest and tilt the workhead to the required secondary clearance angle. Proceed with grinding in the same manner to the required land width.	22. Consult chart of cutter clearance angles.
23. Reverse the cutter on the mandrel and reverse the wheelhead to use the other end of the spindle. Move the workhead $\frac{1}{2}°$ to the left and $3\frac{1}{2}°$ downward tilt. Relocate the tooth rest on the other side of the workhead, on center under the tooth to be ground.	23. Review the principles underlying operation of the tool grinder, including wheel rotation in relation to work being ground.
24. Proceed to sharpen second side of cutter on primary clearance angle.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
25. Lower the tooth rest and tilt the workhead to the same secondary clearance angle. Grind to same land width as first side.	
26. Remove cutter and stone edges lightly to remove any burrs.	26. Handle sharp cutter with extreme care.
27. Submit the cutter for inspection and grade.	

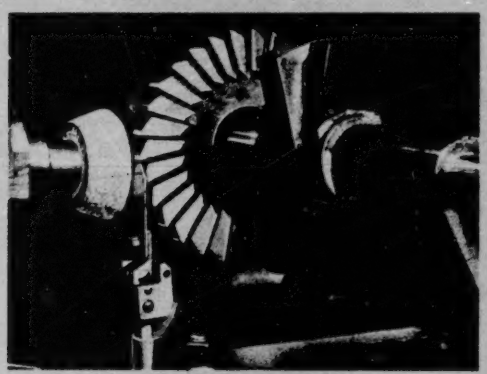

Figure 3-1

(Photos on this page by courtesy of Clausing Corp.)

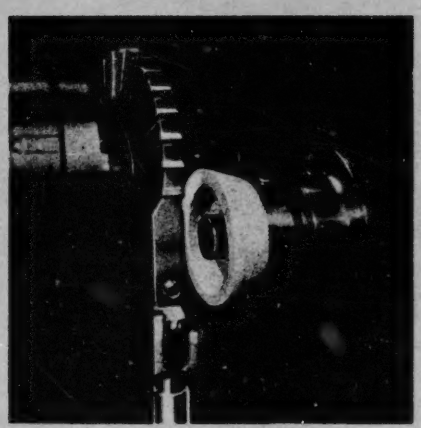

Figure 3-2

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project IV *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Side Milling Cutter (Staggered Teeth) *D.O.T. No.* 603.280

Time: 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding peripheral angular teeth

Materials:
Staggered-tooth side cutter

Equipment:
Tool and cutter grinder
Grinding wheel
Footstock centers
Centering gage
Tooth rest (special)
Cutter-clearance gage
Wheel dresser

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set wheelhead to 89° and attach cup wheel Type No. 11.	
2. Dress wheel sharp and true and dress to a narrow land on the wheel face.	2. Narrow the wheel land with a diamond dresser.
3. Attach a special tooth rest to the wheelhead bringing the high point of the blade on center with the grinding wheel face and centered for height with the centering gage on the table.	3. Review types of tooth rests for special applications. Grind tooth rest to conform with the right- and left-hand helix angles of the cutter and wide enough to project beyond the sides of the cutter.
4. Place the cutter on a mandrel and mount on foot stock centers, locating a tooth on the tooth rest.	
5. Lower the wheelhead or tooth rest the required distance to produce the primary clearance angle desired.	5. Consult a formula or chart to find the required amount to lower the wheelhead. The formula used is: Reqd. angle X dia. of cutter in inches X .0087.
6. With the first tooth on the tooth rest contact the grinding wheel lightly. Hold firmly against the tooth rest and traverse the table in the direction of the tooth angle. The alternate tooth is traversed in the opposite direction. See Fig. 4-1.	6. Mark the starting point with layout dye.

PROCEDURE	TECHNIQUES AND RELATED INFO.
7. Grind all teeth in this manner at the contact setting. Continue grinding until all teeth are sharpened.	7. Inspect the teeth for even cuts on alternate teeth and reset tooth rest to grinding wheel, if necessary. The center of the tooth rest blade must be exactly centered with the face land of the grinding wheel.
8. Lower the wheelhead and tooth rest to grind the secondary clearance angle in the same way the primary angle was ground.	
9. Remove cutter and lightly stone all sharp edges. NOTE: The side teeth of staggered-tooth cutters are not to be sharpened except in special situations.	
10. Submit the cutter for inspection and grade.	

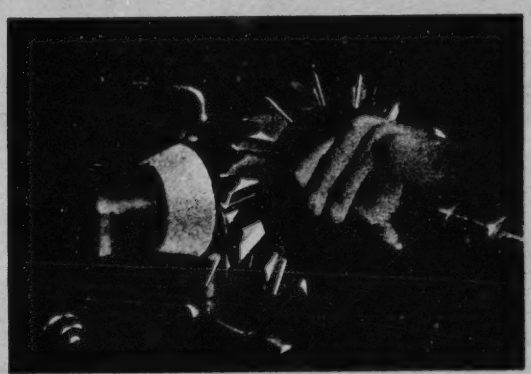

Figure 4-1

(Photo on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project V *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Shell End Mill *D.O.T. No.* 603.280

Time: 5 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding peripheral helical teeth
3. Grinding face teeth

Materials:
Shell end mill

Equipment:

Tool and cutter grinder	Mandrel
Grinding wheel	Stub arbor
Wheel dresser	Center gage
Footstock centers	Tooth rest (offset)
Cutter-clearance gage	Micrometer tooth rest
	Universal workhead

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel wheelhead to 89° and attach cup wheel Type No. 11.	
2. Dress wheel sharp and true.	
3. Attach offset tooth rest to wheelhead and center the high point of the rest with the face land of the grinding wheel. Center the wheelhead and the high point of the tooth rest with the center gage mounted on the table, Fig. 5-1.	3. Review types of tooth rests and their application. Point out the fact that this setup brings all elements on to the same centerline.
4. Set table at 0, place cutter on mandrel, and locate mandrel between centers in footstocks.	
5. Lower the wheelhead and tooth rest enough to provide the primary clearance angle desired.	5. Using the formula, compute the amount to lower the wheelhead. Compare the result with the dial reading for verification.
6. With the first tooth on the tooth rest, contact the grinding wheel lightly. Hold firmly against the tooth rest and traverse the table in the direction of the tooth angle. Traverse the alternate tooth in the opposite direction.	6. Review method of hand holding the mandrel to keep the tooth rest in constant contact with each tooth. Mark the starting tooth with layout dye.

PROCEDURE	TECHNIQUES AND RELATED INFO.
7. Grind all teeth sharp. Check land width.	7. Refer to chart or table to determine correct primary land width.
8. Grind secondary clearance in the same manner by lowering the wheel head further.	
9. Remove footstocks from table and mount work head. Swivel to the right $\frac{1}{2}°$ and down $3\frac{1}{2}°$.	
10. Attach shell end mill to stub arbor and locate in workhead, securely.	10. Use a drawbolt to hold arbor in workhead.
11. Fasten micrometer tooth rest to table and locate blade under peripheral tooth, with the face tooth to be ground in a horizontal plane. See Fig. 5-2.	
12. Lower the wheelhead enough to clear the next tooth above the one being ground.	12. Wheel must be a small diameter cup.
13. Grind the face teeth sharp, holding firmly against the tooth rest at each tooth.	
14. Grind the secondary clearance by lowering the tooth rest and tilting the workhead to the necessary angle.	
NOTE: For sharp corner cutters this completes the grinding. To sharpen the corners of the cutter teeth proceed as follows:	
15. Swivel workhead to 45° on the base and set to 0 on the tilting graduations. Use the centering gage to bring the face tooth level on center with the centerline of the cutter and workhead.	
16. Rotate the cutter the number of degrees recommended for corner clearance and lock the workhead spindle at this angle. Tilt the workhead to the same angle and attach the tooth rest to the table. Set the tooth rest firmly against the tooth to be ground. See Fig. 5-5 on page 31.	16. Explain that two angle settings are necessary when sharpening the tooth corner to prevent heel drag. Because of this the clearance angle is greater and must be set both ways on the workhead
17. Grind the corner teeth sharp, holding each tooth firmly against the tooth rest.	17. Lower the wheelhead to clear the tooth above the one being ground.
18. Remove cutter and lightly stone the edges to remove all burrs.	
19. Submit the cutter for inspection and grade.	

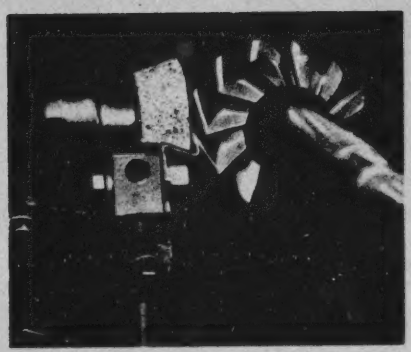

Figure 5-1

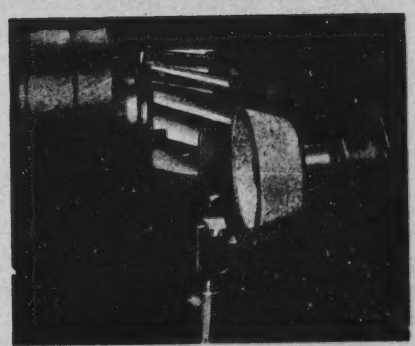

Figure 5-2

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project V *Project Name:* Cutter Grinding

Job No. 2 *Job name:* Carbide-Tooth Cutter (Shell End Mill) *D.O.T. No.* 603.280

Time: 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Mounting and truing a diamond grinding wheel
2. Grinding of carbide cutter

Equipment:
Tool and cutter grinder
Type No. 11 grinding wheel
Wheel dresser
Dial indicator
Universal workhead
Arbor
Tooth rest

Materials:
Carbide-tipped shell end mill

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set the wheelhead at 0°, attach a diamond-grit cup wheel, and true up the face of the wheel with a dial indicator. See Fig. 5-3.	1. Review wheel types including diamond concentration, and methods of wheel truing. Check the specifications on diamond wheel runout.
2. Mount cutter on arbor, locate it in the workhead, and grind the top face of each tooth.	2. Wheel should rotate into cutting edge. Review rake angles for positive and negative radial rake. Use a silicon carbide wheel if much material is to be removed.
3. Grind each tooth face to correct the radial angle. Grind each tooth in turn to sharpen the cutting edges.	3. Check tooth rest setting for equal spacing. Use indexing methods, if required. Restrict depth of cut to .001" or less. Use a recommended coolant to prevent overheating and checking of the carbide.

PROCEDURE	TECHNIQUES AND RELATED INFO.
4. Relocate the workhead and the tooth rest to grind the periphery of the cutter. See Fig. 5-4.	4. Locate tooth rest on the grinding wheelhead with a finger $1\frac{1}{2}$ times the length of the carbide tip.
5. Grind the primary angle.	5. The diamond grinding wheel should rotate into the cutting edge. Consult manufacturer's tables for recommended clearances.
6. Lower the spindle and grind the secondary clearance angle.	
7. Relocate the workhead and the tooth rest to grind the front face of the teeth.	7. Mount the tooth rest on the table so the radial angle of the tooth is level with the table.
8. Tilt the workhead to the desired clearance angle and swivel it to 1°.	8. Grind each tooth in turn using .001" maximum depth of cut.
9. Grind the 45° chamfer of the corners of the teeth with the workhead parallel. Rotate the cutter the required amount for the type of radial rake on cutter. See Fig. 5-5.	9. Consult manufacturer's tables to obtain correct settings.
10. Hone the cutter teeth after sharpening with a hand stone.	10. Use a 400- to 500-grit hand hone.
11. Submit the cutter for inspection and grade.	

Figure 5-3

(Photos on this page and page 31 by courtesy of Norton Co.)

Figure 5-4
Grinding the Periphery

Figure 5-5
Grinding a Corner

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project V *Project Name:* Cutter Grinding

Job No. 3 *Job name:* Corner Radius Grinding (Shell End Mill) *D.O.T. No.* 603.280

Time: 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Form wheel dressing
2. Radius form grinding
3. Table alinement using dial indicator

Equipment:
Spindle extension
Type No. 1. grinding wheel
Dressing sticks
Offset rounded-head tooth rest
Radius-grinding attachment
Cutter arbor
Centering gage
Dial indicator
Radius gage
Cutter-clearance gage

Materials:
Shell end mill

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Mount the radius-grinding attachment on the left side of the machine table and adjust the table, the spindle, and the attachment to their zero settings. See Fig. 5-6.	1. Clean and inspect all surfaces to be sure they are free of burrs and dirt.
2. Attach a spindle extension to the spindle, swivel the wheel head to 45° and mount a 6" x $\frac{1}{2}$" Type No. 1 grinding wheel. Use a wheel guard.	2. Inspect the grinding wheel for for cracks and fractures.
3. True and dress the corner of the wheel facing the work to the desired radius, with the high spot at the point of contact with the cutter.	3. Use a suitable carborundum or norbide dressing stick.
4. Attach offset rounded-head tooth rest to the wheelhead. See Fig.5-7	4. Set it in front of the high spot of the wheel.
5. Using the centering gage on the wheelhead, aline the high point of the tooth rest with the center of the grinding-wheel spindle.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Mount the attachment workhead on the table of the radius-grinding attachment, and mount the cutter in the workhead using a suitable arbor.	6. Use the T-slot most suitable for the size of cutter to be ground.
7. Aline the workhead spindle with the grinding wheel spindle. Locate the corner of the tooth that is to be ground over the pivotal point of the attachment by eye.	
8. Place the guidepost gage firmly against the periphery and the face of the tooth to be ground. Rest the spindle of the workhead either parallel to or perpendicular to the table.	8. Note that the design of the radius-grinding attachment may dictate other setup procedures.
9. Attach a dial indicator to the workhead grinding wheel workhead and indicate the guidepost periphery to a zero-zero runout by adjusting both slides.	9. Set attachment swivel stops to a 90° swing.
10. Set the micrometer on both slides of the attachment at zero. Advance both slides an equal amount for the radius desired and lock them.	10. Zero-reference the dial settings.
11. By means of the crossfeed and the table traverse of the machine table, bring the cutter into contact with the wheel in position for grinding, locating the corner of the tooth to be ground on the point of the tooth rest.	
12. Lower the wheelhead to the clearance desired.	12. Check a suitable clearance chart.
13. Grind all teeth to the desired radius.	13. Use the crossfeed or the topslide for the depth of cut desired. CAUTION: Do not take too deep a cut as it may burn the cutter teeth.
14. Adjust for secondary clearance angle and grind all teeth.	14. Do not do this operation unless it is necessary. CAUTION: Be careful not to contact the tooth above the one being ground.
15. Submit for inspection and grade.	15. Use local shop practices.

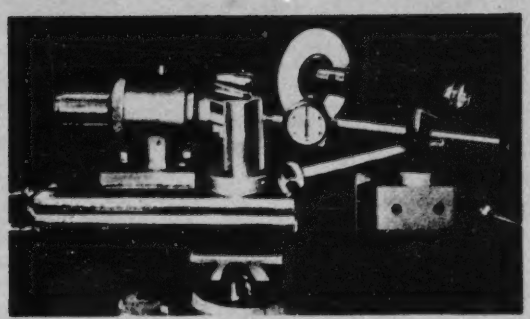

Figure 5-6

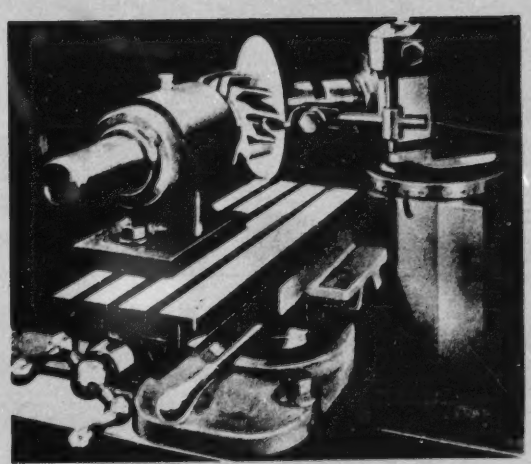

Figure 5-7

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project VI *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Slotting Cutter *D.O.T. No.* 603.280

Time: 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding peripheral teeth

Materials:
$\frac{3}{16}$" x 4" slotting cutter

Equipment:

Cutter grinder	Footstock centers
Grinding wheel	Mandrel
Wheel dresser	Clearance-setting dial
Micrometer tooth rest	Clearance-setting dog
Cutter-clearance gage	

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel wheel head to 89° and attach cup wheel Type No. 11. See Fig. 6-1.	
2. Dress wheel sharp and true.	
3. Aline the wheelhead spindle with the centering gage on the table.	
4. Attach the micrometer tooth rest to the table and adjust the blade to centering gage height.	4. Review types of tooth rests and their application.
5. Place cutter on mandrel and locate between centers with clearance-setting dial and dog in place.	
6. Locate tooth on the tooth rest blade with the dial at 0.	
7. Insert clamp dog in clearance gage and clamp to mandrel. Lower the tooth rest and rotate it to the required clearance.	7. Refer to a chart for proper clearance angle.
8. Lock the clearance dial and raise the tooth rest firmly against the tooth to be ground. Remove dog and proceed with grinding.	8. Mark starting tooth with layout dye. Grind until all teeth are sharp. Use light cuts on thin cutters.
9. Check width of land and grind secondary clearance if needed.	9. Refer to a chart for recommended land width and secondary angle.
10. Remove cutter from mandrel and lightly stone teeth to remove sharp burrs.	
11. Submit for inspection and grade.	

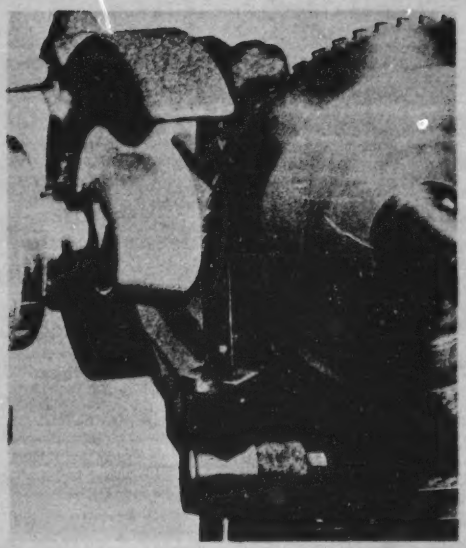

Figure 6-1

(By courtesy of LeBlond Inc., Cincinnati, Ohio.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project VII *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Angular Cutters (60°) *D.O.T. No.* 603.280

Time: 3 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding face teeth
3. Grinding angular teeth

Materials:
60° angular cutter

Equipment:
Cutter grinder
Grinding wheel
Wheel dresser
Universal workhead
Cutter-clearance gage
Stub arbor
Center gage
Tooth rest

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the grinding wheelhead to 89° with table at 0 and attach cup wheel type No. 11. See Figs. 7-1 and 7-2.	1. Review setup procedures to grind end or face teeth.
2. Dress wheel sharp and true.	2. Follow shop practice.
3. Mount universal workhead on table, swivel $\frac{1}{2}°$ to the right and tilt down $3\frac{1}{2}°$.	3. Review work holding attachments.
4. Attach angular cutter to stub arbor and insert into workhead.	4. Use a drawbolt for secure hold.
5. Locate tooth rest on table. With peripheral tooth on tooth rest, center the blade with the centerline of the cutter.	5. Face tooth will be in a horizontal plane for sharpening.
6. Lower the wheelhead to clear the tooth above the tooth being ground.	
7. Hold the cutter tooth firmly against the tooth rest and grind the face teeth sharp, using light cuts.	
8. To grind the angular teeth, set the workhead at 0 and swivel the table to 30°.	
9. Bring the tooth rest up to the centerline of the cutter and rest the tooth to be ground firmly on the blade.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
10. Adjust the clearance graduations on the workhead to 0 and lock in place. 11. Lower the tooth rest and rotate the cutter in the workhead to 7°. Clamp them in these positions and proceed to grind the teeth. 12. If secondary clearance is needed, do the following: With all adjustments in the same position lower the tooth rest and rotate the cutter to the desired secondary clearance angle. Then proceed with grinding. 13. Submit for inspection and grade.	12. Check the width of land and refer to a standard chart or table for the secondary clearance angle.

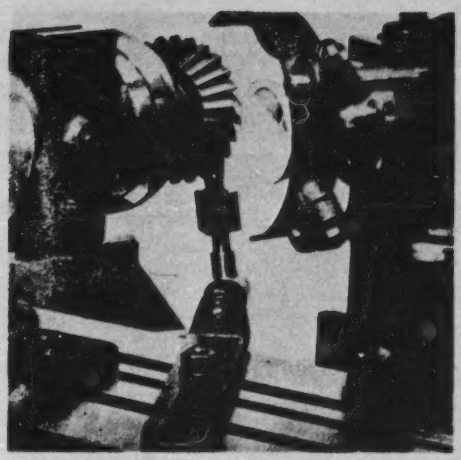

Figure 7-1
(By courtesy of LeBlond Inc., Cincinnati, Ohio.)

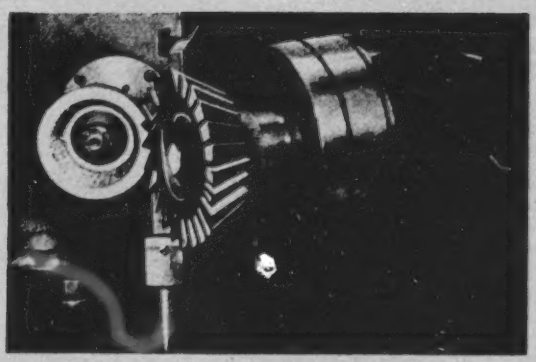

Figure 7-2
(By courtesy of Clausing Corp.)

Unit *Operator's job title:* Universal Tool Grinder Operator

Project VIII *Project Name:* Cutter Grinding

Job No. 1 *Job name:* End Mill (4-flute) *D.O.T. No.*603.280

Time: 3 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding end teeth
3. Grinding helical teeth

Materials:
4-flute end mill

Equipment:
Cutter grinder
Grinding wheel
Wheel dresser
Universal workhead
Cutter-clearance gage
End mill collet
Center gage
Tooth rest
Footstock centers

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel wheelhead to $89\frac{1}{2}°$ and attach cup wheel type No. 11, with table set at zero.	1. Follow shop practice to dress and true up grinding wheel.
2. Locate workhead on the table, with base graduations at 0 and tilt head down $3\frac{1}{2}°$.	
3. Mount end mill in workhead and locate tooth rest on the table to grind end teeth. See Fig. 8-1.	
4. Bring tooth rest blade up under the tooth to be ground at right angles with the spiral of the teeth, to a point opposite the center of the cutter.	4. NOTE: For end mills a narrower tooth rest blade may be needed.
5. Lower the wheelhead to clear the tooth next above the one being ground and grind the end teeth.	
6. Grind secondary clearance, if needed, by lowering the tooth rest blade and tilting the workhead down to 10°.	
7. For sharpening the peripheral teeth locate the wheelhead at 89°. Then attach offset tooth rest to wheelhead and center it with centering gage.	7. Review tooth rest types for helical teeth.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Place end mill between centers in footstocks mounted on the table, and locate tooth to be ground on the centered tooth rest.	8. Wheel face must be dressed for a narrow contact area.
9. Lower the wheelhead and rotate the cutter to the desired clearance angle. Proceed with grinding, holding the tooth being ground firmly against the tooth rest blade.	9. Check table of clearance angles to figure amount to lower head.
10. Secondary clearance is ground in the same manner by lowering the wheel further to produce the required angle.	10. Check width of land to determine whether secondary clearance is needed.
11. Submit for inspection and grade.	

Figure 8-1

(Photos on this page by courtesy of Clausing Corp.)

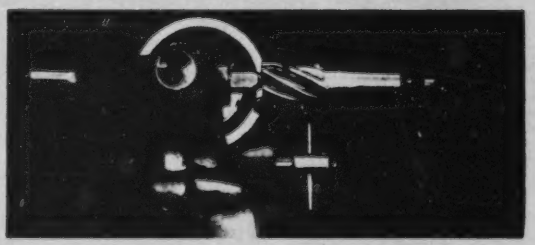

Figure 8-2

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project IX *Project Name:* Cutter Grinding

Job No. 1 *Job name:* T-Slot Cutter *D.O.T. No.*603.280

Time: 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding peripheral teeth
3 Grinding side teeth

Materials:
Straight-tooth T-slot cutter

Equipment:
Tool and cutter grinder
Grinding wheel
Wheel dresser
Centering gage
Work centers
Cutter-clearance gage
Tooth rest
Universal workhead
Wheelhead extension
Dish wheel

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 89° and attach cup wheel Type No. 11.	
2. Dress wheel sharp and true.	2. Follow shop practice. Keep wheel face narrow.
3. Attach micrometer tooth rest to table and center the tooth rest blade.	
4. Locate the cutter between centers with the tooth to be ground on the tooth rest blade. See Fig. 9-1.	
5. Lower the tooth rest using the micrometer adjustment, to provide a 7° clearance angle.	5. Refer to table of cutter diameters and clearance angles.
6. Grind the teeth, holding each tooth firmly against the tooth rest.	
7. Grind the secondary clearance by lowering the tooth rest further to provide the necessary angle.	
8. To grind the face or end teeth attach the workhead to the table, swivel $\frac{1}{2}°$ to the right and tilt down $3\frac{1}{2}°$. See Fig. 9-2.	
9. Position the cutter in the workhead. Bring the tooth rest blade	9. Tooth rest is mounted on the table.

on center with the cutter, with the peripheral tooth resting on the tooth rest blade.	
10. Lower the grinding wheel head to clear the tooth above the one being ground. Sharpen the end teeth, holding each tooth firmly against the tooth rest.	
11. To grind the side teeth toward the shank of the cutter swivel the work-head $\frac{1}{2}°$ to the left and tilt up $3\frac{1}{2}°$.	
12. Attach the extension to the grinding wheel spindle and mount a dish wheel Type No. 12 with the rim toward the wheel head.	12. Review attachments and wheel types.
13. Dress the wheel rim to a narrow land.	
14. Raise the tooth rest to the centerline of the cutter with the peripheral tooth resting on the tooth rest blade.	14. Tooth rest must be positioned to avoid contact with the grinding wheel.
15. Adjust the table to contact the tooth to be ground with the rim of the dish wheel. Set the table stop to prevent contact with the shank of the cutter.	
16. Lower the wheelhead enough to clear the tooth next above the one being ground and sharpen the side teeth.	
17. Submit the cutter for inspection and grade.	

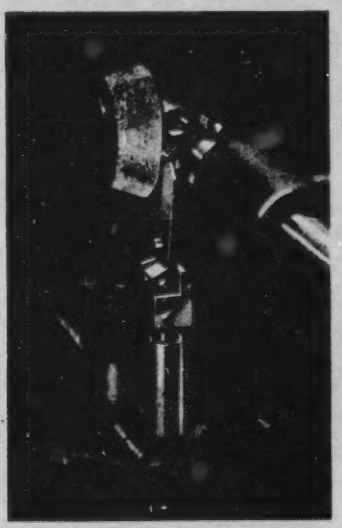

Figure 9-1

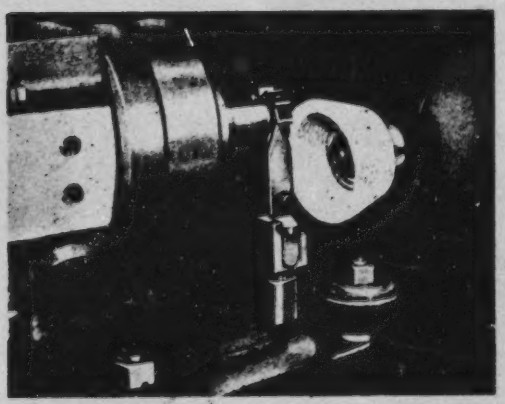

Figure 9-2

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project X *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Form-Relieved Milling Cutter (between work centers) *D.O.T. No.* 603.280

Time: 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $^{+1^\circ}_{-\frac{1}{2}^\circ}$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding form-relieved teeth

Materials:
Form-relieved milling cutter

Equipment:

Cutter grinder	Tooth rest
Grinding wheel	Mandrel
Wheel dresser	Wheel extension arbor
Footstock centers	Height gage

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the grinding wheelhead to 90°. Attach spindle extension and 6" dish wheel, type No. 12, with rim facing out. See Figs. 10-1 and 10-2.	1. Review attachments and wheel types.
2. Dress wheel sharp and true, keeping a medium land.	
3. Place cutter on mandrel and mount between centers on the table, with the face of the tooth on top, toward the wheelhead.	
4. Set table at 0. Adjust the height of the wheelhead so the dish wheel covers the face of the tooth to be ground.	
5. Line up the face of the tooth with the cutting face of the wheel in a radial position.	5. The ground face of the tooth should always be in the center of the cutter diameter. Check this with a height gage.
6. Attach the micrometer tooth rest to the table and locate it against the back of the tooth to be ground.	
7. Hold the cutter firmly against the tooth rest and grind the face of each tooth in turn. Use the micrometer tooth rest for infeed to maintain the radial grind.	7. The backs of the teeth must be uniform to locate each tooth for proper grinding. Grind the backs of the teeth first if necessary.
8. Submit the cutter for inspection and grade.	

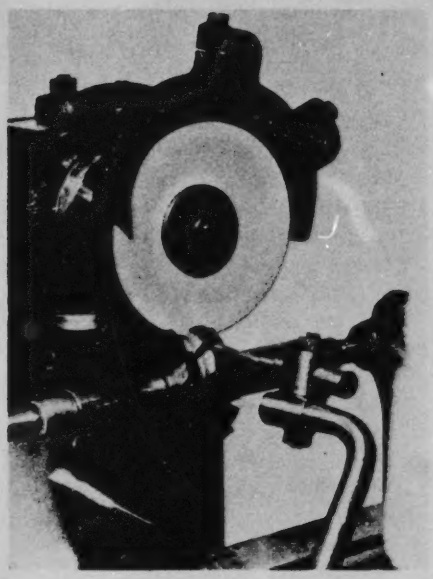

Figure 10-1
(By courtesy of LeBlond Inc., Cincinnati, Ohio.)

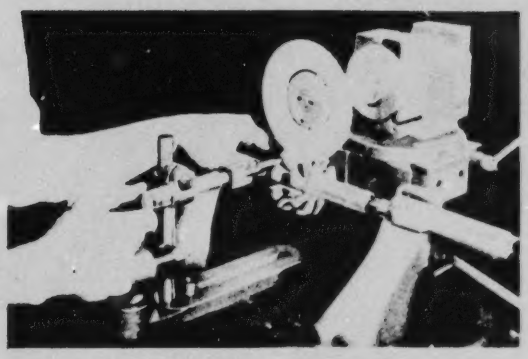

Figure 10-2
(By courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XI *Project Name:* Cutter Grinding

Job. No. 1 *Job name:* Face Milling Cutter (Inserted Teeth) *D.O.T. No.* 603.280

Time: 5 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Face grinding

Materials:
Face milling cutter (inserted teeth)

Equipment:

Tool and cutter grinder	Arbor
Type No. 2 grinding wheel	Centering gage
Wheel dresser	Tooth rest
Universal workhead	

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 89°. See Figs. 11-1A and 11-1B.	
2. Mount a type No. 11 grinding wheel.	2. Use wheel blotters and flange washers.
3. Dress wheel sharp and true.	3. Use local shop practice.
4. Attach offset tooth rest to the wheelhead with the high point alined with the spindle and rim of the cup wheel.	4. Review types of tooth rests and settings for grinding.
5. Adjust the column to center the tooth rest using the centering gage on the table.	
6. Mount the workhead on the machine table and adjust all settings to zero. Locate the face mill in the workhead to grind the peripheral teeth.	
7. With the tooth to be ground on the tooth rest, lower the column enough to establish the clearance angle.	7. Consult a table of clearance-angle settings.
8. Hold each tooth firmly against the tooth rest blade and grind all teeth alike.	8. Be careful to avoid grinding wheel contact with the tooth above.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Grind the secondary clearance by lowering the head and tooth rest and grinding to the required land.	9. Review a table showing clearance angles and recommended lands.
10. To grind the face or end teeth swivel the workhead $89\frac{1}{2}°$ and tilt it down $3\frac{1}{2}°$.	10. Check references for recommended clearancee angle for the material to be machined.
11. Locate the micrometer tooth rest on the table with the blade under a peripheral tooth. Adjust it until a face tooth is on a parallel plane with the machine table. See Fig. 11-2.	
12. Lower the wheelhead to clear the tooth above the tooth to be ground. Grind each of the face teeth until all are sharp.	12. Be careful not to burn the teeth.
13. To grind the secondary clearance on the face teeth, lower the tooth rest and tilt the workhead to recommended angle.	13. Locate the tooth rest as in step 11.
14. Grind the secondary angle to achieve the proper land.	14. Consult a table of clearance angles.
15. To grind the corner chamfer on the face mill teeth, swivel the table to 45° and swivel the workhead back to zero. See Fig. 11-3.	
16. Tilt the workhead down to the clearance angle.	
17. Lower the tooth rest blade and rotate the cutter to the desired clearance angle.	17. Review double angle settings for grinding tooth corners.
18. Reset the tooth rest under the tooth to be ground. Hold the tooth firmly against the tooth rest and proceed with the grinding.	
19. Submit the cutter for inspection and grade.	

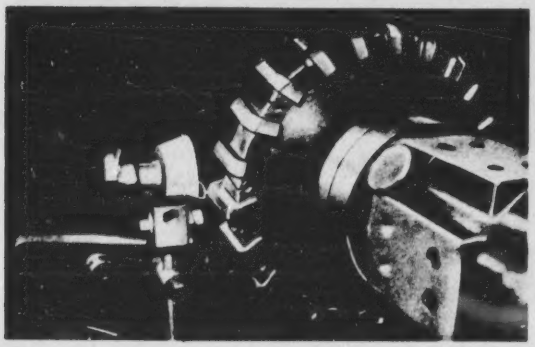

Figure 11-1A

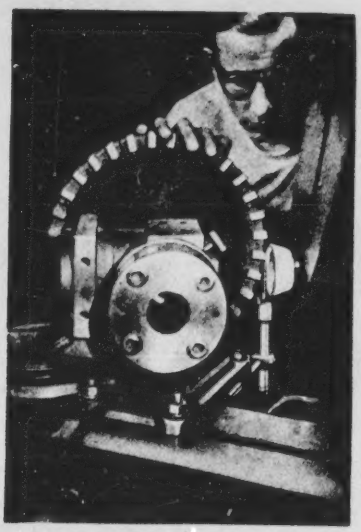

Figure 11-1B
Method for Cutters of Extra-large Diameter

(Photos on this page and page 47 by courtesy of Clausing Corp.)

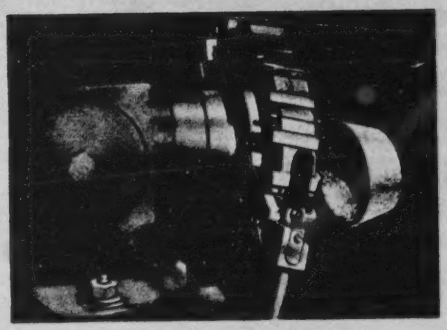

Figure 11-2

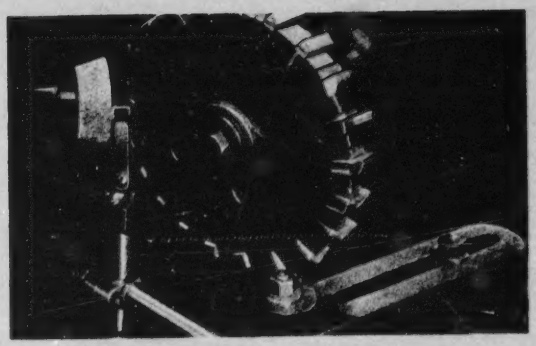

Figure 11-3

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XII *Project Name:* Cutter Grinder

Job No. 1 *Job name:* Form Cutter (Involute Gear Cutter) *D.O.T. No.* 603.280

Time: 3 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named for use on a designated material. Rake and clearance angles are to be accurate to $^{+1^\circ}_{-\frac{1}{2}^\circ}$. Surface finish is to meet a visual comparison standard. After completing this job the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Radial face grinding

Equipment:
Tool and cutter grinder
Type 12 grinding wheel
Gear cutter grinding attachment
Spindle extension
Cutter bushing
Wheel dresser

Materials:
Involute gear cutter

Selected references:
Cincinnati cutter and tool grinder operator's instruction book
McCarthy & Smith. *Machine tool technology;* 3d edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set up gear cutter grinding attachment near the center of the worktable and adjust the table to zero.	1. Use the proper machine cleaning techniques.
2. Set up a type No. 12 grinding wheel, using a spindle extension adapter.	2. Use the correct wrenches to avoid damage to the spindle and adapter flats.
3. Swivel the wheelhead to 90°.	
4. Place the gear cutter on the stud of the gear cutter grinding attachment. Line up the face of the tooth to be ground with the centering gage of the attachment. Adjust the pawl of the attachment firmly against the heel of the tooth to be ground. See Fig. 12-1.	4. To obtain proper alinement it may be necessary to grind the backs of the teeth first to obtain uniform seating of the pawl. This is accomplished by reversing the cutter on the attachment and lining it up with the cutting face of the grinding wheel, holding the front of the tooth against the pawl while grinding the back of the tooth.

PROCEDURE	TECHNIQUES AND RELATED INFO.
5. Lower or swing the gage out of the way, adjust the face of the wheel to the face of the tooth being ground, and proceed with the grinding. With the screw adjustment on the pawl, feed the work to the wheel to maintain radial grinding.	5. Set table traverse stop.
6. Index to the next tooth by turning the cutter on the stud, backing up the next tooth firmly against the pawl. See Fig. 12-2.	6. Do not readjust the pawl until all of the teeth have been ground at the same setting.
7. Swivel the table to the desired degree of undercut and line up the face of the tooth with the face of the grinding wheel.	7. This operation applies only if the cutter is provided with rake or undercut teeth. Look up information as to cutter rake angle in a manufacturer's catalog.
8. Submit the cutter for inspection and grade.	

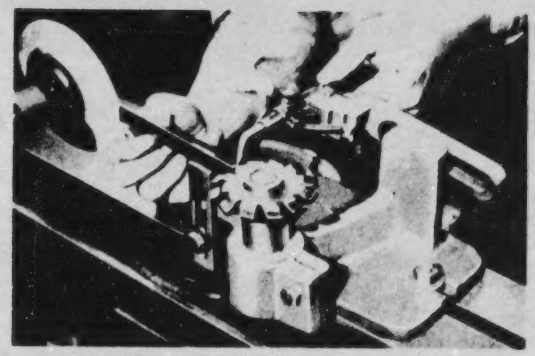

Figure 12-1

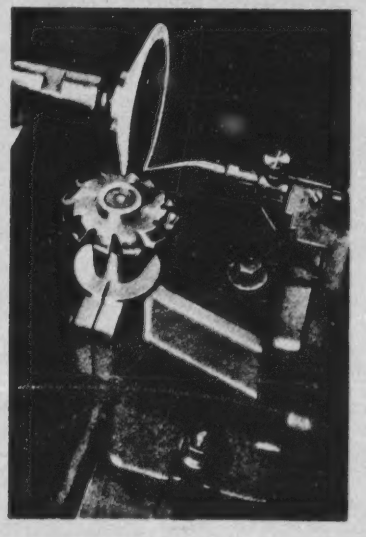

Figure 12-2

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XIII *Project Name:* Cutter Grinding

Job No. 1 *Job Name:* Spot Facing Tool *D.O.T. No.* 603.280

Time: $1\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding face teeth

Materials:
Spot facing tool

Equipment:
Tool and cutter grinder
Type No. 11 grinding wheel
Universal workhead
Centering gage
Plain straight-tooth rest
Dial indicator

Selected references:
Anderson & Tatro. *Shop theory;* 6th edition
Manufacturer's literature

PROCEDURES	*TECHNIQUES AND RELATED INFO.*
1. Remove the pilot from the spot-facing tool. See Fig. 13-1.	1. Look for a recessed screw to release the pilot. If there is no screw, use a pin-punch of proper size to knock out the pilot from the back of the cutter. Caution: Protect the cutting edges at all times.
2. Swivel the workhead 89° and attach a Type No. 11 cup wheel.	
3. Adjust machine table to zero.	3. Use a dial indicator.
4. Attach a universal workhead and insert the shank of the tool in the workhead. Set all dials of the workhead at zero except the base; swivel the base to 90°.	4. Use the proper size draw-in collet if the tool is of straight shank design. Use a tapered sleeve if the tool is of taper-shank design.
5. Tilt the workhead down to the desired clearance angle and lock it in place.	5. Check for proper clearance angle in a suitable reference book.

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Attach the tooth rest to the table and bring it up under the tooth to be ground in line with the center of the cutter. Hold the cutter firmly against the tooth rest and traverse the table.	6. Be sure to set the table traverse stops to stop in the center of the cutter diameter.
7. When all teeth have been ground, check to see that they are perfectly straight and of equal height, then take a very light finishing cut.	7. Use local shop inspection methods.
8. Submit the spot facing tool for inspection and grade.	

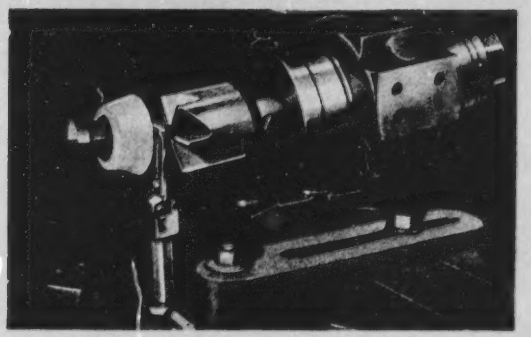

Figure 13-1

(Photo on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XIV *Project Name:* Cutter Grinding

Job No. 1 *Job Name:* Straight Reamer *D.O.T. No.* 603.280

Time: 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Cylindrical grinding
3. Grinding secondary angles
4. Grinding chamfered teeth

Materials:
Straight-tooth reamer

Equipment:
Type Nos. 1 and 11 grinding wheels
Motor-driven headstock
Footstock centers
Micrometer tooth rest
Tool grinder
Driving dog
Wheel dresser

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Adjust the table and wheelhead to zero, and center the wheel spindle with the centering gage set on the table. See the illustrations on the next two pages.	1. Use a dial indicator for table alinement.
2. Attach a 6" x $\frac{1}{2}$" Type No. 1 grinding wheel and dress it sharp and true. Fig. 14-1.	2. Review proper mounting and truing techniques.
3. Mount the motor-driven workhead and footstock and locate the reamer between centers with a driving dog attached.	3. Review attachments and their uses.
4. Grind the reamer cylindrically to the required diameter. See Fig. 14-2.	4. Reamer blades must rotate to contact the grinding wheel with heel first. This is done to reduce the size of the reamer more rapidly. Check for proper taper.
5. Grind the secondary clearance by	

swiveling the wheelhead to 89° and attaching a type No. 11 cup grinding wheel.	
6. Attach a micrometer tooth rest to the table and center the blade with the centering gage. Lower the blade to the proper secondary clearance angle.	6. Refer to a reamer cutting-angle chart. See Fig. 14-3.
7. Hold the tooth to be ground firmly against the tooth rest blade and grind the secondary clearance, leaving .025" for a primary land.	7. Primary land is determined by the materials the reamer is to machine. Refer to a suitable chart.
8. To grind the ends of the reamer blades (teeth), swivel the wheelhead 40° and attach a type No. 12 dish wheel. See Fig. 14-4.	
9. Attach a micrometer tooth rest to the table and center it with the centering gage.	
10. Insert the reamer between centers and work it up to the grinding wheel. Adjust the table traverse to the proper position and lock it in position.	
11. Use the crossfeed to advance the work back and forth.	11. Be sure to lock the table traverse.
12. After all teeth have been ground, readjust the table traverse for another depth of cut. Repeat the process until the desired results are obtained.	12. Grind all teeth exactly to the same length.
13. Swivel the table to 45° and grind the beveled corners to the desired width. Use the same clearance setting used in grinding the secondary clearance on the periphery. See Fig. 14-5.	
14. Oilstone the feathered edges and submit the reamer for inspection.	14. Use local shop practice.

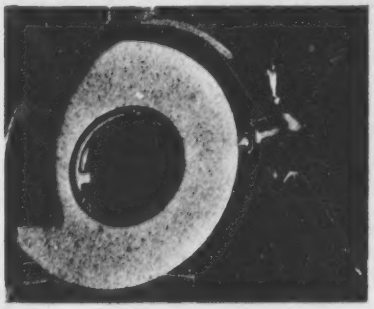

Figure 14-1

(Photos on this page and page 54 by courtesy of Clausing Corp.)

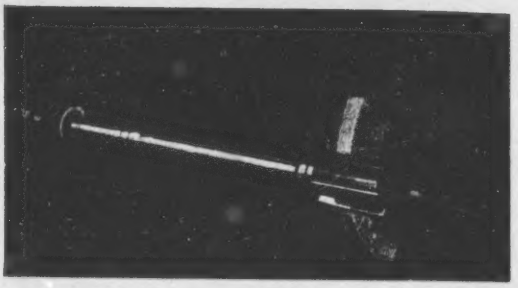

Figure 14-2

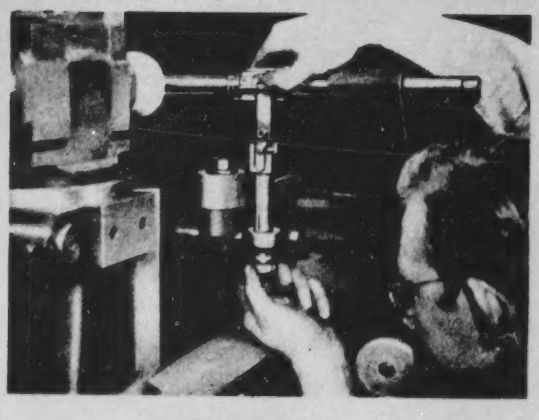

Figure 14-3

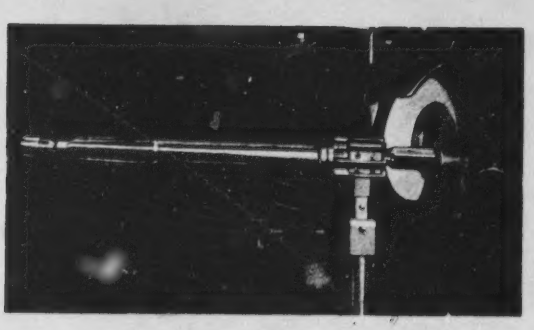

Figure 14-4

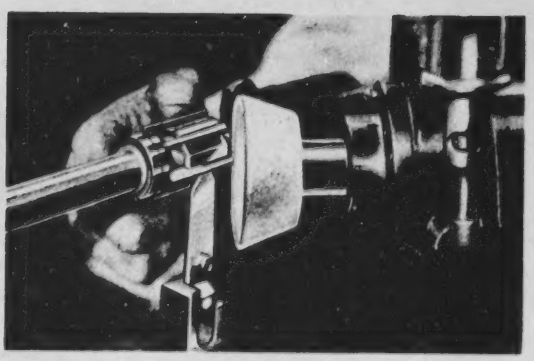

Figure 14-5

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XV *Project Name:* Cutter Grinding

Job No. 1 *Job Name:* Fly Cutter (Double-edged) *D.O.T. No.* 603.280

Time: 3 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding face teeth to a shoulder
3. Periphery grinding

Materials:
Fly cutter mounted on a driving arbor

Equipment:
Tool grinder
Types No. 11 & 12 grinding wheels
Footstock centers
Centering gage
Straight micrometer tooth rest
Wheel dresser
Clearance-setting dial
Clamp dog

Selected references:
Anderson & Tatro. *Shop theory;* 6th edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. To grind the periphery, swivel the wheelhead to 89° and mount a type No. 11 cup wheel.	1. Be sure the wheel flanges are clean and free of nicks and burrs. Use wheel absorbing blotters.
2. Attach a micrometer tooth rest to the machine table and center it with the centering gage. See Figs. 15-1 and 15-2.	2. Be sure the table surface is clean and free of dirt. Use a straight tooth rest finger.
3. Drop the tooth rest half the thickness of the cutter blade.	
4. Attach the clearance-setting dial to the left-hand footstock and insert the cutter arbor between the centers.	
5. Insert the clamp dog in the opening of the arbor. Do this with the cutting blade resting on the tooth rest and the clearance-setting dial at zero.	5. Be sure the center holes are clean and that both work centers are free of nicks and dirt.

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Lower the tooth rest and rotate the cutter downward to the degree of clearance desired. Clamp the tooth rest firmly against the cutter blade.	6. Check for proper clearance angle in relation to the material the fly cutter will be applied too. Use a suitable reference chart.
7. Remove the clamp dog, hold the cutter firmly against the tooth rest, and grind the periphery of the cutter blade.	7. Be sure not to force the blade down on the tooth rest.
8. Attach a dish wheel type No. 12 and swivel the wheelhead to 60°. See Fig. 15-3.	8. Check the grinding wheel for cracks and fractures before mounting.
9. Insert clamp dog into opening in clearance-setting dial, clamp to arbor, and rotate cutter blade upward until clearance-setting dial reads zero. Raise the tooth rest against the cutting blade and clamp into position.	
10. Remove dog clamp from arbor, traverse table to proper position for grinding, and lock the table traverse. With the crossfeed, bring work in contact with edge of grinding wheel, which should be elevated to produce a suitable cutting clearance angle.	10. Check cutter clearance reference tables.
11. When grinding the face, use the crossfeed to pass the work back and forth on the grinding edge of the wheel. As the blade is ground, advance the table traverse between passes until the desired land width is reached.	11. Check with a suitable reference book to obtain the recommended width. Be careful not to damage the edge of the cutting blade on the periphery.
12. Remove all feather edges with a suitable stone and submit the cutter for inspection and grade.	12. Use local shop practice for inspection.

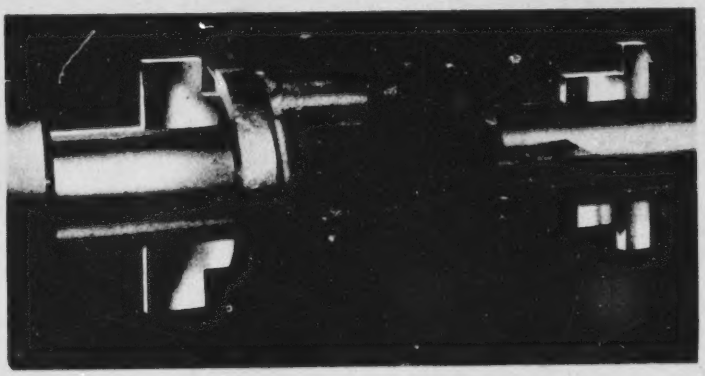

Figure 15-1
(Photos on this page and page 57 courtesy of Clausing Corp.)

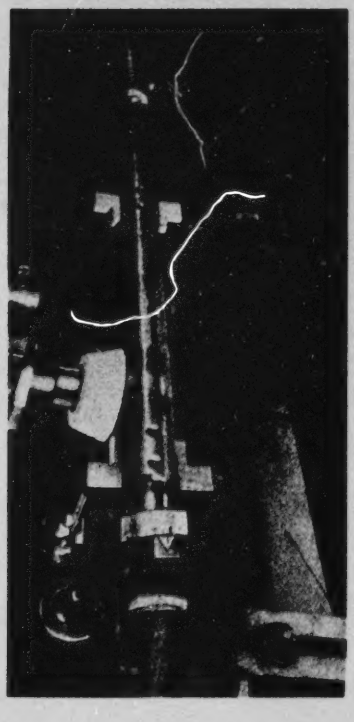

Figure 15-2

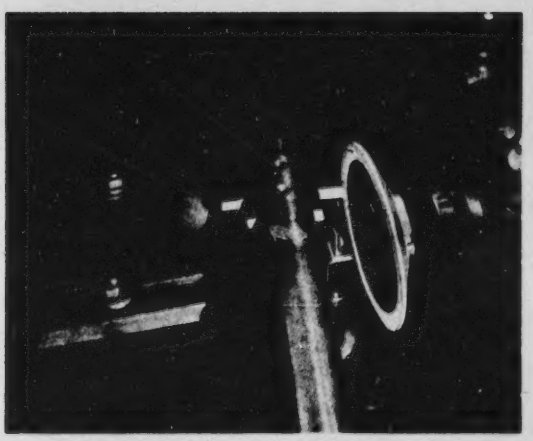

Figure 15-3

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XVI *Project Name:* Cutter Grinding

D.O.T. No. 603.280

Job No. 1 *Job name:* Grinding an Angular Cutter into a Form Cutter *Time:* 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Grinding between centers
3. Angular grinding
4. Form grinding

Materials:
45° angle cutter

Equipment:

Universal tool and cutter grinder	Wheel dresser
Type No. 11 grinding wheel	Tooth rest
	Extension spindle
	Mandrel

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Swivel the wheelhead to 90°, attach a spindle extension, and set up a type No. 11 cup grinding wheel. See Fig. 16-1.	1. Use a suitable wheel guard. NOTE: The procedure here describes one technique of transforming an angular cutter for cutting the spiral teeth on a milling cutter. The teeth on this cutter must have the proper curvature for forming a hook on the teeth of the milling cutter.
2. Attach a micrometer tooth rest to the worktable and bring it up alongside the column, with the blade pointed toward the worktable. See Fig. 16-2.	2. The finger will contact the face teeth of the angular cutter.
3. Place the cutter on a mandrel and the mandrel between centers.	
4. Adjust the table to zero and set the cutter to be ground perpendicular with the axis. Place the tooth rest blade firmly against this tooth.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
5. Adjust or lower the tooth rest for the desired clearance (or use the clearance-setting dial).	5. Refer to a suitable table of clearance settings.
6. Bring the cutter into the proper position for grinding and lock the table traverse. Using the crossfeed, bring the work to the grinding wheel and grind each tooth in turn. After grinding all teeth, advance the table and repeat the operation until the proper curvature and depth are achieved.	6. The cup wheel must have the diameter of the curvature desired on the cutter. See Fig. 16-1.
7. Set up the cutter grinder to grind the corners of the angular cutter as follows: Center the tooth rest on the table with a centering gage. Adjust the tooth to be ground against the tooth rest, using a clearance-setting dial. Adjust the tooth rest for the desired clearance and clamp it in position. See Fig. 16-2.	7. Check for clearance specifications.
8. Remove the extension spindle and attach a type No. 11 cup wheel to the spindle. Lower the wheelhead to proper grinding position.	
9. Adjust the worktable to zero and grind off sharp corners.	
10. Swivel the worktable $22\frac{1}{2}°$ and grind the corners on the 45° side of the cutter.	10. Back the grinding wheel away from the cutter before swiveling the table, to prevent damage to the grinding wheel.
11. Swivel the table 45° in the opposite direction and grind the corner on the 90° side of the cutter.	
12. Swivel the table $22\frac{1}{2}°$ and grind this corner.	
13. Swivel the table $67\frac{1}{2}°$ and grind this corner.	
14. When all grinding is complete, submit the cutter for inspection and grade.	

NOTE: Fig. 16-3 shows an application of the cutter.

(Photos on this page and page 60 by courtesy of Clausing Corp.)

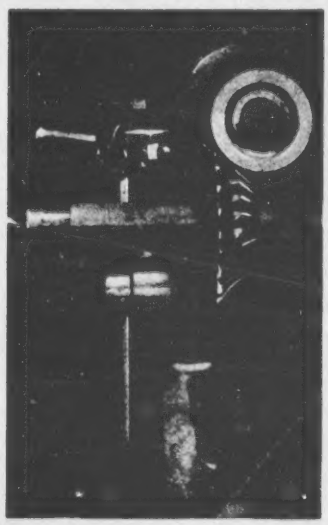

Figure 16-1

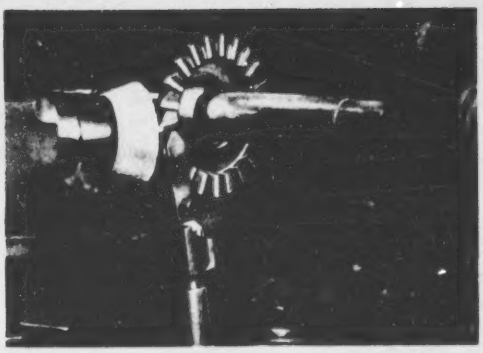

Figure 16-2
Grinding the Corners

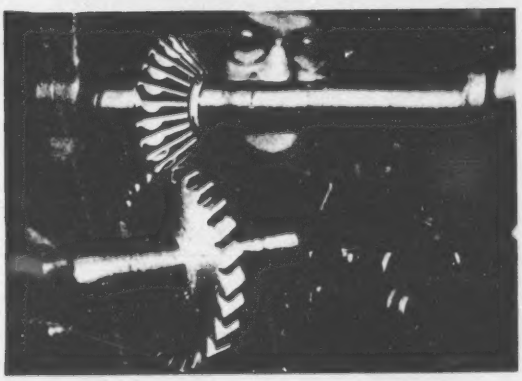

Figure 16-3
An Application of the Cutter

(Photos on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XVII *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Fellows Spur Gear Cutter *D.O.T. No.* 603.280

Time: $1\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Face grinding

Materials:
A suitable Fellows gear cutter

Equipment:
Diamond dressing tool
Universal workhead and motor
Centering gage
Type No. 1 grinding wheel
Stub arbor

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Center the grinding wheel spindle and attach a $\frac{1}{2}$" x 6" type No. 1 grinding wheel to the left end of the spindle. Dress the wheel. See Fig. 17-1.	1. Use the centering gage on the table. Use a diamond dressing tool.
2. Swivel the table 180° and mount a universal workhead attachment and set the attachment at zero.	2. Clean the table and the attachment base.
3. Attach a motor drive to the universal workhead attachment and set the attachment at zero.	3. Calculate r/min of the work and select the proper pulleys.
4. Swivel the worktable to provide the desired cutter rake angle.	4. Look up rake recommendations in a suitable reference book.
5. Mount the cutter on a stub arbor and insert it in the workhead spindle.	5. Clean the arbor and the spindle hole.
6. Bring the work and the grinding wheel into contact.	6. The work must rotate in the opposite direction from the grinding wheel.
7. Hand traverse the work, covering its entire surface.	7. Set the traverse stop to halt the table at the center of the cutter.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Continue to take roughing cuts until the desired sharpness is obtained.	8. Limit the depth of cut to .001" or .002" when roughing.
9. Dress the grinding wheel and take several finishing cuts.	9. Depth of finishing cuts is to be limited to .0001".
10. Submit the cutter for inspection and grade.	

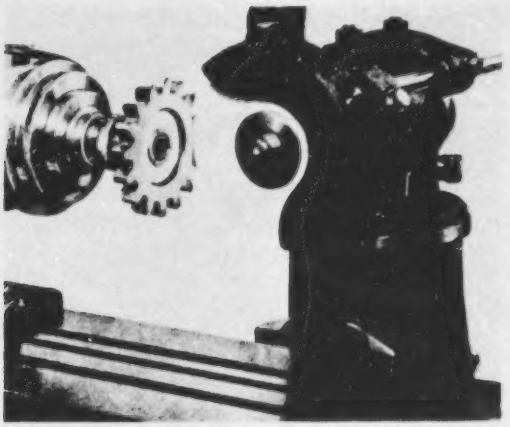

Figure 17-1
(Courtesy of LeBlond Inc., Cincinnati, Ohio.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XVIII *Project Name:* Cutter Grinding

Job No. 1 *Job name:* 60° Form Tap (Between centers) *D.O.T. No.* 603.280

Time: 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Grinding wheel form dressing
2. Plunge grinding between centers

Equipment:
Head and footstock centers
Collet or chuck
Universal tooth rest
Type No. 1 grinding wheel
Dressing stick
Universal workhead

Materials:
60° UNC starting tap
Prussian blue

Selected references:
Cincinnati cutter and tool grinder operator's instruction book
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set the worktable to zero and the wheelhead perpendicular to the T-slot.	
2. Set up left- and right-hand footstocks. Clamp them to the table properly spaced for the tap to be sharpened.	2. Hold small taps with a collet or a chuck in a universal workhead.
3. Place tap between centers (or in workhead).	
4. Fasten the universal tooth rest assembly to the table with the blade against the back of tooth to be ground.	4. Grind the backs of the teeth first, if necessary.
5. Mount the grinding wheel and wheel guard to the spindle and wheelhead. Use a type No. 1 grinding wheel.	5. The grinding wheel thickness must be smaller than the width of the flutes of the tap.
6. Dress the wheel with a carborundum stone (or stick) shaped like the flute of the tap.	
7. Adjust saddle to centerline of the tap, using approximately the same centerline as the grinding wheel.	
8. Grind one side of flute making sure not to destroy the original shape of the flute as manufactured. Index and	8. Prussian blue can be applied as an aid in determining if tap and

PROCEDURE	TECHNIQUES AND RELATED INFO.
grind all remaining flutes.	wheel are positioned correctly. Little stock removal is necessary to sharpen a tap in this manner. NOTE: Taps are normally sharpened by grinding to the lead. The procedure outlined here should be used only if absolutely necessary.
9. Submit the tap for inspection and grade.	

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XVIII *Project Name:* Cutter Grinding

Job No. 2 *Job name:* 60° Form Tap (Using a Tap-grinding Attachment) *D.O.T. No.* 603.280

Time: 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $^{+\frac{1}{2}}_{-2}$°. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Wheel dressing
2. Taper grinding
3. Cutoff grinding

Materials:
60° UNC starting tap

Equipment:
Tool grinder
Type No. 1 grinding wheel
Tap-grinding attachment
Cutoff grinding wheel
Centering gage
Finger rest
Diamond dresser

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Mount a type No. 1 grinding wheel and a wheel guard.	
2. Bring the wheelhead to center height using the centering gage.	
3. Set up a tap-grinding attachment and set the base swivel to the same angle as the taper on the end of the tap to be sharpened. See Fig. 18-1.	
4. Dress the grinding wheel. Set the wheelhead angle 1° more than the angle of the attachment setting.	
5. Mount the tap in the grinding fixture and set finger rest behind tooth to be ground.	5. Large taps are held between centers and indexed by the use of a tooth rest. Small taps are held in this attachment by a chuck which is equipped with a rachet stop.
6. Grind each taper alike with the proper clearance behind each cutting edge.	6. The required taper and clearance are produced by adjustment of the attachment and grinding the tap while oscillating the handle on the head of the attachment.

PROCEDURE	TECHNIQUES AND RELATED INFO.
7. If the taper of the tap becomes too long then the end of the tap must be cut off. Set up a cutoff grinding wheel and a wheel guard.	7. Be sure to check the wheel for cracks and fractures. Use a spry or flood coolant.
8. Set the attachment at zero and locate grinding wheel at position for cutoff operation.	8. Lock the table traverse and hand feed the cross-feed.
9. Submit the tap for inspection and grade.	

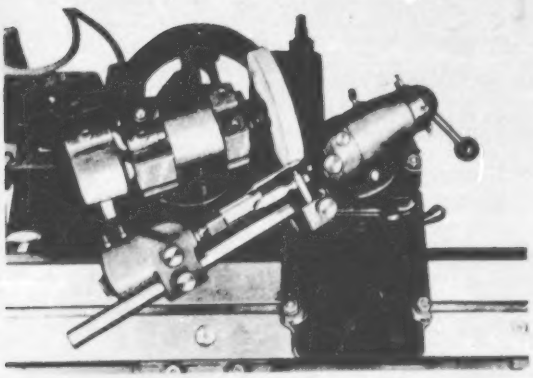

Figure 18-1

(Photo on this page by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XIX *Project Name:* Cutter Grinding

Job No. 1 *Job name:* Milled Thread Chaser *D.O.T. No.* 603.280

Time: $1\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Surface grinding of compound angles
2. Wheel dressing

Materials:
Milled thread chasers

Equipment:
Tool grinder
Spindle extension
Type No. 1 grinding wheel
Chaser attachment or toolmaker's grinding vise

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Attach a spindle extension and mount a 6" x $\frac{1}{2}$" type No. 1 grinding wheel. Use a wheel guard. See Fig. 19-1.	1. Use an aluminum oxide wheel, 46-S6 vitrified, or comparable wheel.
2. Swivel the wheelhead to 90° and raise the wheelhead high enough to allow the work to swing under the grinding wheel.	
3. Clamp the thread chaser grinding attachment on the worktable and adjust the worktable to zero. Place a chaser in the attachment and lock it.	
4. Adjust the attachment dial to the angle required for sharpening.	
5. Bring the chamfered portion of the chaser directly under the wheel in a grinding position. Traverse the work and lower the grinding wheel to contact the work. Grind until the chaser is sharp.	5. When the chamfer is completely sharpened, note the dial reading of the elevating mechanism. Do not pass this setting in grinding the remaining chasers in the set.
6. Remove the first chaser and continue by grinding the remaining units in the set.	6. Be sure each chaser is clean and perfectly seated so that all will be ground alike.

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PROCEDURE	TECHNIQUES AND RELATED INFO.
7. To grind the face of the milled chaser, dress the corner of the wheel to conform to the curvature of the chaser face.	7. NOTE: This operation is seldom required.
8. Mount the chaser in the attachment in such a position that the face of the chaser will come into contact with the grinding wheel. See Fig. 19-2.	8. Make sure the attachment and chaser are clean for accurate seating of the chaser.
9. Adjust the attachment to the angle required.	
10. Adjust the work to the wheel and traverse it past the grinding face of the wheel.	10. Take light cuts especially in finishing. Note the dial reading on the elevating screw. Do not pass this point in grinding successive chasers in the set.
11. Remove the chaser and grind the remaining chasers in the set.	
12. Submit the chasers for inspection and grade.	

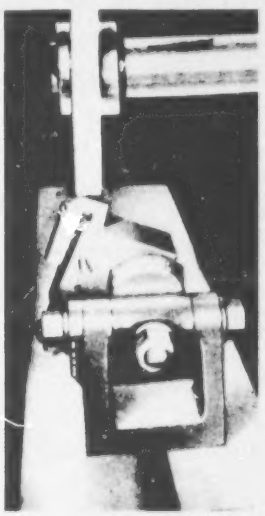


Figure 19-1
Grinding a Chamfer

(Photos on this page by courtesy of Clausing Corp.)

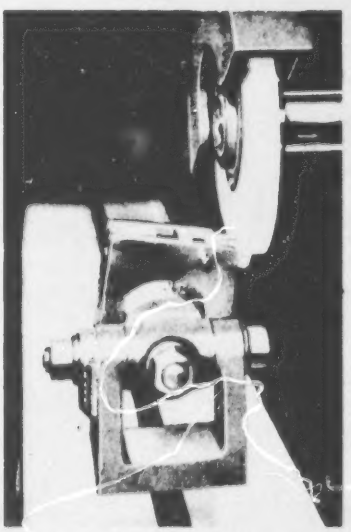


Figure 19-2
Grinding the Face

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XIX *Project Name:* Cutter Grinding

Job No. 2 *Job name:* Tangent Chaser *D.O.T. No.* 603.280

Time: $2\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $^{+1^\circ}_{-\frac{1}{2}^\circ}$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Face grinding
2. Wheel dressing
3. Angle grinding

Materials:
Tangent chasers

Equipment:
Universal tool grinder
Diamond dresser
Grinding wheel
Chaser grinding attachment

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. To grind or sharpen the rake angle, attach an extension spindle to the grinding wheel spindle.	1. Use a suitable wheel guard.
2. Attach a suitable type No. 1 grinding wheel.	2. Use an aluminum oxide 46-S6 vitrified wheel.
3. Adjust the table to zero, mount the chaser grinding attachment to the worktable and position it for grinding. See Fig. 19-3.	3. Be sure all parts are clean.
4. Swivel the attachment to the proper angle to produce the rake and lead angles desired.	4. Use the manufacturer's recommendations.
5. Grind the rake angle until the chaser is sharp. Note the elevating dial setting.	5. Start the sharpening process by selecting the dullest chaser of the set.
6. Repeat steps 3, 4, and 5 with all the other chasers in the set.	
7. When the lead angle is achieved, readjust the attachment angle to conform to the recommended lip rake angle. Continue grinding as in steps 5 and 6. See Fig. 19-4.	
8. When all chasers in the set are completely ground, submit them for inspection and grade.	

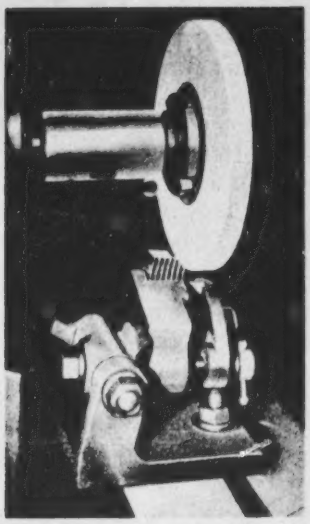


Figure 19-3
Grinding the Top Rake

(Photos on this page by courtesy of Clausing Corp.)

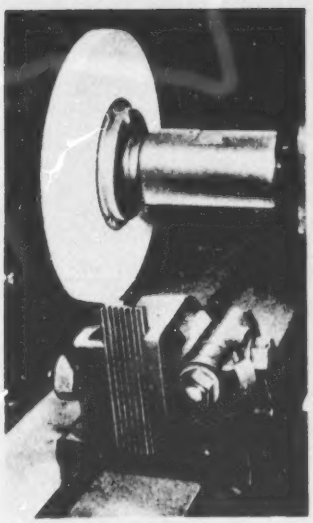


Figure 19-4
Grinding the Lip Rake Angle

Unit No. | *Operator's job title:* Universal Tool Grinder Operator

Project XX | *Project Name:* Cutter Grinding

Job No. 1 | *Job name:* Lathe Forming Tool for Die Wrench Handle | *D.O.T. No.* 603.280

Time: $2\frac{1}{2}$ hours

Drawing No. 73

Performance Objectives:
Using only the equipment and materials listed here, the student will, in the time specified, be able to correctly sharpen the cutter named, for use on a designated material. Rake and clearance angles are to be accurate to $\pm\frac{1}{2}°$. Surface finish is to meet a visual comparison standard. After completing this job, the student will be able to complete similar jobs with like requirements.

Operations:
1. Form dressing using a hand dressing stone
2. Form dressing using a radius-dressing attachment
3. Radius form grinding.

Equipment:
Universal tool grinder
Type No. 1 grinding wheel
Radius-dressing attachment
Dressing stick
Universal grinding vise
Radius gage

Materials:
$\frac{3}{8}$" square Rex AAA tool bit or equivalent.

Selected references:
Anderson & Tatro. *Shop theory;* 6th edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set up a type No. 1 plain grinding wheel using a spindle extension and a wheel guard.	1. Check the wheel for cracks and fractures. Use a wheel $\frac{1}{2}$" x 6".
2. Set the machine table at zero and the wheelhead at 90°.	
3. Rough dress the grinding wheel to $\frac{1}{4}$" radius.	3. Use a suitable dressing stick. Set up a dust collecting hood. Be sure to use eye protection.
4. Mount a radius dresser with a diamond nib and dress a $\frac{1}{4}$" convex radius on the grinding wheel.	4. Follow the manufacturer's directions for proper setting of the dressing attachment.
5. Remove the dressing attachment and mount a universal angle vise.	5. Be sure to clean the table.
6. Set up the vise to allow the proper front and side clearances on the radius-forming tool.	6. Consult a suitable handbook for clearance angles and compound angle settings.
7. Clamp the $\frac{3}{8}$" square tool bit in the vise in an upright position.	7. Use a solid square to aline the tool bit.
8. Aline the formed grinding wheel with the tool bit by eye.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Lower the grinding wheel while traversing the table and rough-grind the form tool.	
10. Redress the grinding wheel to $\frac{1}{4}$" radius.	10. Redress to compensate for wheel wear in the roughing operation.
11. Finish grind the radius to the specified depth and stone the feathered edges. Submit the forming tool for inspection and grade.	

Unit No. *Operator's title:* Universal Tool Grinder Operator

Project XXI *Project Name:* Surface Grinding

Job No. 1A *Job name:* Parallels (inches) *D.O.T. No.* 603.280

Drawing No. 50A *Time:* 6 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing
2. Grinding parallel
3. Grind square
4. Plunge grinding

Materials:
Workpiece from Heat Treat:
(tool steel) $\frac{1}{2}$" x $\frac{3}{4}$" x 6"
2 pcs. required:
.530" x .780" x 6.030"

Equipment:

Universal tool grinder	Surface gage
Type No. 1 grinding wheel	Dial indicator
Grinding vise	Micrometer
Angle plate	Diamond wheel dresser
Parallel clamps	Magnetic chuck
Surface plate	

Selected references;
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Remove the burrs from the heat-treated parallels and check for a warped condition.	1. Parallels should always be machined in matched pairs.
2. Turn the wheel spindle at right angles to the worktable and mount a wheel spindle extension.	
3. Mount a type No. 1 plain grinding wheel and a suitable wheel guard.	
4. Set up a magnetic chuck and clamp to the machine worktable.	4. Be sure to clean all mating parts. Indicate and aline the back rail.
5. Set up a wet grinding attachment and dress the grinding wheel.	5. Dress the wheel wet.
6. Locate the first piece in the grinding vise with the $\frac{3}{4}$" side up and level it with an indicator.	6. Level both ends of the part to the same indicator reading. Check again after tightening the vise. Use an indicator and surface gage.
7. Set the grinding vise on a magnetic chuck.	7. Contact the highest point with the grinding wheel

PROCEDURE	TECHNIQUES AND RELATED INFO.
	and grind the surface until it is clean.
8. Repeat the setup and grind the second part.	
9. Locate the ground surfaces of both parts on the magnetic chuck and grind opposite sides to clean up parallel.	9. Be sure to clean all burrs from the parallels. Also clean the surface of the magnetic chuck.
10. Check the depth of the $\frac{1}{8}$" x $\frac{3}{8}$" cut on each side of both pieces. Finish grind to .500" dimension, keeping the $\frac{1}{4}$" web centrally located.	10. Use a micrometer. CAUTION: One parallel may have more warp than the other. For the finish sizes, both parallels should be ground together.
11. Locate one of the pieces on a precision angle plate and clamp it securely with one edge $\frac{1}{16}$" above the top of the angle plate. Grind to clean up.	11. Keep the $\frac{1}{2}$" side facing up. Level the ends with a dial indicator and a surface gage on a surface plate.
12. Repeat the above operation with the second part.	
13. Locate both parts on a magnetic chuck and grind opposite surfaces clean.	
14. Check the $\frac{3}{8}$" dimension (undercut) and grind the parts to .750".	14. Finish grind both parallels together. Keep the $\frac{3}{8}$" wide undercut centrally located.
15. Set up a type No. 1 grinding wheel and dress it true and clean.	15. Don't forget to reset the wheel guard. Use a wheel of proper width for the slot.
16. Locate both parts against the back rail of the magnetic chuck end to end, and grind the $\frac{3}{8}$" undercut to clean it up.	16. Use a downfeed method (plunge-cut method) while traversing the table.
17. Turn the parts over and grind the rest of the webbed section to clean up.	17. Remove all burrs and clean chuck of grinding particles.
18. Remove all sharp edges and submit the parallels for inspection and grade.	18. Use a stone.

Unit No. *Operator's title:* Universal Tool Grinder Operator

Project XXI *Project Name:* Surface Grinding

Job No. 1B *Job name:* Parallels (millimeters) *D.O.T. No.* 603.280

Drawing No. 50B *Time:* 6 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing
2. Grinding parallel
3. Grind square
4. Plunge grinding

Materials:
Workpiece from heattreat. (tool steel)
2 pcs. required:
13mm x 19mm x 150mm

Equipment:

Universal tool grinder	Surface gage
Type No. 1 grinding wheel	Metric dial indicator
Grinding vise	25mm micrometer
Angle plate	Diamond wheel dresser
Parallel clamps	Magnetic chuck
Surface plate	

Selected references;
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Remove the burrs from the heat-treated parallels and check for a warped condition.	1. Parallels should always be machined in matched pairs.
2. Turn the wheel spindle at right angles to the worktable and mount a wheel spindle extension.	
3. Mount a type No. 1 plain grinding wheel and a suitable wheel guard.	
4. Set up a magnetic chuck and clamp to the machine worktable.	4. Be sure to clean all mating parts. Indicate and aline the back rail.
5. Set up a wet grinding attachment and dress the grinding wheel.	5. Dress the wheel wet.
6. Locate the first piece in the grinding vise with the 19mm side up and level it with a metric dial indicator.	6. Level both ends of the part to the same indicator reading. Check again after tightening the vise. Use the indicator and a surface gage.
7. Set the grinding vise on a magnetic chuck.	7. Contact the highest point with the grinding wheel and grind the surface

PROCEDURE	TECHNIQUES AND RELATED INFO.
	until it is clean.
8. Repeat the setup and grind the second part.	
9. Locate the ground surfaces of both parts on the magnetic chuck and grind opposite sides to clean up parallel.	9. Be sure to clean all burrs from the parallels. Also clean the surface of the magnetic chuck.
10. Check the depth of the 3.5 x 10mm cut on each side of both pieces. Finish grind to 13mm dimension, keeping the 6mm web centrally located.	10. Use the metric micrometer. CAUTION: One parallel may have more warp than the other. For the finish sizes, both parallels should be ground together.
11. Locate one of the pieces on a precision angle plate and clamp it securely with one edge 2mm above the top of the angle plate. Grind to clean up.	11. Keep the 13mm side facing up. Level the ends with a dial indicator and a surface gage on a surface plate.
12. Repeat the above operation with the second part.	
13. Locate both parts on a magnetic chuck and grind opposite surfaces clean.	
14. Check the 10mm dimension (undercut) and grind the parts to 19mm.	14. Finish grind both parallels together. Keep the 10mm wide undercut centrally located.
15. Set up a type No. 1 grinding wheel and dress it true and clean.	15. Don't forget to reset the wheel guard. Use a wheel of proper width for the slot.
16. Locate both parts against the back rail of the magnetic chuck end to end, and grind the 10mm undercut to clean it up.	16. Use a downfeed method (plunge-cut method) while traversing the table.
17. Turn the parts over and grind the rest of the webbed section to clean up.	17. Remove all burrs and clean chuck of grinding particles.
18. Remove all sharp edges and submit the parallels for inspection and grade.	18. Use a stone.

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXII *Project Name:* External Cylindrical Grinding

Job No. 1A *Job Name:* Lathe Mandrel (inches) *D.O.T. No.* 603.280

Drawing No. 34A *Time:* 3 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing (diamond)
2. Straight cylindrical grinding

Materials:
Lathe mandrel (from lathe projects)
Center lubricant

Equipment:

Universal tool grinder	1" micrometer
Type No. 1 grinding wheel	Centering gage
Diamond wheel dresser	60° lap
Motorized workhead	Drive dog
R.H. tailstock and center	Headstock center and sleeve
Dial indicator	Coolant system
Gage blocks	
Electronic gage block comparator	

Selected references:
Anderson & Tatro. *Shop theory;* 6th edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES*
1. Place a motor-driven workhead and a right-hand tailstock on the machine table. Position the wheelhead at the proper height for the worktable.	1. Place them so the workpiece will be centrally located. This will make it simpler to adjust for taper and straight grinding.
2. Mount a type No. 1 plain grinding wheel on the spindle with a suitable wheel guard.	
3. Set up a coolant nozzle for application of a flood coolant.	3. Review information on suitable grinding coolants and how to mix them.
4. Dress the grinding wheel using a diamond dresser.	4. Keep the coolant directed at the contact point of the grinding wheel and the diamond
5. Lap the center holes of the mandrel (workpiece) using a centerhole lap.	5. Follow local shop practice.
6. Clamp the drive dog to the workpiece. Set the workpiece between centers. See Fig. 22-1.	6. Use a suitable center lubricant and adjust the

PROCEDURE	TECHNIQUES AND RELATED INFO.
	tailstock tension to suit the workpiece.
7. Set the wheel speed to cover the proper number of surface feet per minute.	7. Use a reference chart for grinding wheel speeds.
8. Set workpiece speed for the material to be ground.	8. Refer to a suitable reference book. Convert the findings to r/min.
9. Set the table traverse stops and take a trial cut over the entire length of the workpiece.	9. The grinding wheel should traverse off the workpiece by $\frac{1}{2}$ to $\frac{2}{3}$ the width of the grinding wheel.
10. Set the machine to produce .0005" taper per inch.	10. Use a micrometer which reads to .0001".
11. Proceed to rough-grind the diameter within .002" or .003" of the finished dimension.	11. Use coolant.
12. Redress the grinding wheel and continue to grind to finish dimension.	12. Be sure to spark out on the last .001" to eliminate the spring or deflection. Decrease the traverse feed rate for a better finish. Use an electronic gage block comparator.
13. Submit the mandrel for inspection and grade.	

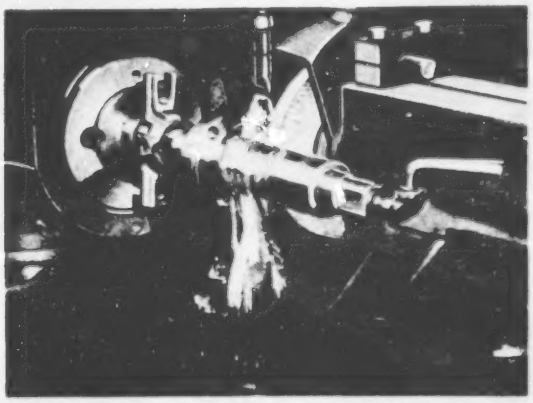


Figure 22-1
External Cylindrical Grinding

NOTE: The illustration above is provided as general guidance only for a typical cylindrical grinding operation. It may not give very much information that is of *specific* use. (Photo is by courtesy of Clausing Corp.)

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXII *Project Name:* External Cylindrical Grinding

Job No. 1B *Job Name:* Lathe Mandrel (millimeters) *D.O.T. No.* 603.280

Drawing No. 34B *Time:* 3 [illegible]rs

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing (diamond)
2. Straight cylindrical grinding

Materials:
Lathe mandrel (from lathe projects)
Center lubricant

Equipment:

Universal tool grinder	25mm micrometer
Type No. 1 grinding wheel	Centering gage
Diamond wheel dresser	60° lap
Motorized workhead	Drive dog
R.H. tailstock and center	Headstock center and sleeve
Metric dial indicator	Coolant system
Metric gage blocks	
Metric electronic comparator	

Selected references:
Anderson & Tatro. *Shop theory;* 6th edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Place a motor-driven workhead and a right-hand tailstock on the machine table. Position the wheelhead at the proper height for the worktable.	1. Place them so the workpiece will be centrally located. This will make it simpler to adjust for taper and straight grinding.
2. Mount a type No. 1 plain grinding wheel on the spindle with a suitable wheel guard.	
3. Set up a coolant nozzle for application of a flood coolant.	3. Review information on suitable grinding coolants and how to mix them.
4. Dress the grinding wheel using a diamond dresser.	4. Keep the coolant directed at the contact point of the grinding wheel and the diamond.
5. Lap the center holes of the mandrel (workpiece) using a centerhole lap.	5. Follow local shop practice.

PROCEDURE	TECHNIQUES AND RELATED INFO.
6. Clamp the drive dog to the workpiece. Set the workpiece between centers. See Fig. 22-1 on page 78.	6. Use a suitable center lubricant and adjust the tailstock tension to suit the workpiece.
7. Set the wheel speed to cover the proper number of surface feet per minute.	7. Use a reference chart for grinding wheel speeds.
8. Set workpiece speed for the material to be ground.	8. Refer to a suitable reference book. Convert the findings to r/min.
9. Set the table traverse stops and take a trial cut over the entire length of the workpiece.	9. The grinding wheel should traverse off the workpiece by $\frac{1}{2}$ to $\frac{2}{3}$ the width of the grinding wheel.
10. Check for taper. Set the machine to produce .017mm taper per 25mm.	10. Use a 25mm metric micrometer.
11. Proceed to rough-grind the diameter within .06 or .08mm of the finished dimension.	11. Use coolant.
12. Redress the grinding wheel and continue to grind to finish dimension.	12. Be sure to spark out on the last .025mm to eliminate the spring or deflection. Decrease the traverse feed rate for a better finish. Use an electronic comparator set with metric gage blocks for final size.
13. Submit the mandrel for inspection and grade.	

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXIII *Project Name:* External Cylindrical Grinding

Job No. 1A *Job name:* Lathe Dieholder (inches) *D.O.T. No.* 603.280

Drawing No. 18A *Time:* 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel truing and dressing
2. Cylindrical grinding to a shoulder
3. Table alinement (with indicator)
4. Work truing (with indicator)

Equipment:

Universal tool grinder	Type No. 1 grinding wheel	
Motorized workhead	1" micrometer	
4-jaw chuck	Gage blocks	
Centering gage	Electronic comparator	
Diamond dresser		
Dial indicator		

Materials:
Workpiece from lathe projects.
4 pieces of aluminum or brass to protect the workpiece

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set worktable at zero. See Fig. 23-1.	1. Use a dial indicator.
2. Aline the table and wheel height in proper relationship to each other.	2. Use the centering gage provided with the machine.
3. Set up and adjust the motorized workhead to zero.	3. Clean all mating surfaces.
4. Mount a 4-jaw chuck on the workhead spindle.	
5. Clamp the sliding holder in the chuck and true it up.	5. Use a soft material between the jaws and the workpiece to avoid damage to the knurl.
6. Set the wheelhead to zero and mount a type No. 1 grinding wheel.	6. Clean the wheel flanges and use blotters. Use a wheel guard.
7. True and dress the grinding wheel.	7. Use a diamond dressing attachment clamped to the worktable.
8. Locate the grinding wheel against the $2\frac{3}{4}$" shoulder to set the table stops for rough-grinding the 1.000" diameter.	8. Set the left-hand traverse stop to avoid removing excess material from the shoulder.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Traverse the table towards the $2\frac{3}{8}$" diameter shoulder and rough-grind to 1.002" thickness.	
10. Redress the grinding wheel if necessary and finish grind to 1.000" plus or minus .0002".	10. Check the left-hand traverse stop to be sure the grinding wheel will not override the shoulder of the workpiece. Use gage blocks and an electronic comparator to check dimensions.
11. Clean the machine and all tools.	
12. Submit the dieholder for inspection and grade.	

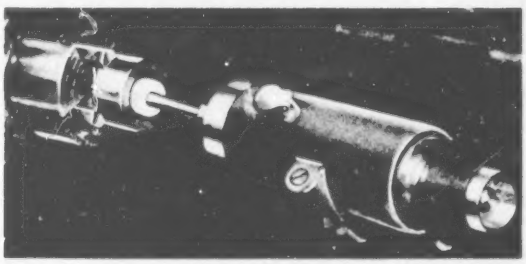


Figure 23-1
(Courtesy of Clausing Corp.)

Note: The illustration above applies only as general guidance for the grinding operation and may not provide very much information that applies specifically. It is helpful not only for Jobs 1A and 1B of Project XXIII, but also for the following:

Project XXVI, Arbor Press Sleeve, Jobs 1A and 1B
Project XXVII, Die Wrench, Job 1
Project XXVIII, Taper Ring Gage, Jobs 1A and 1B

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXIII *Project Name:* External Cylindrical Grinding

Job No. 1B *Job name:* Lathe Dieholder (millimeters) *D.O.T. No.* 603.280

Drawing No. 18B *Time:* 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel truing and dressing
2. Cylindrical grinding to a shoulder
3. Table alinement (with indicator)
4. Work truing (with indicator)

Equipment:
Universal tool grinder
Motorized workhead
4-jaw chuck
Centering gage
Diamond dresser
Metric dial indicator
Type No. 1 grinding wheel
50mm micrometer
Metric gage blocks
Metric electronic comparator

Materials:
Workpiece from lathe projects
4 pieces of aluminum or brass to protect the workpiece

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set worktable at zero. See illustrations.	1. Use a dial indicator.
2. Aline the table and wheel height in proper relationship to each other.	2. Use the centering gage provided with the machine.
3. Set up and adjust the motorized workhead to zero.	3. Clean all mating surfaces.
4. Mount a 4-jaw chuck on the workhead spindle.	
5. Clamp the sliding holder in the chuck and true it up.	5. Use a soft material between the jaws and the workpiece to avoid damage to the knurl.
6. Set the wheelhead to zero and mount a type No. 1 grinding wheel.	6. Clean the wheel flanges and use blotters. Use a wheel guard.
7. True and dress the grinding wheel.	7. Use a diamond dressing attachment clamped to the worktable.
8. Locate the grinding wheel against the 60.3mm shoulder to set the table stops for rough-grinding the 25.4mm diameter.	8. Set the left-hand traverse stop to avoid removing excess material from the shoulder.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Traverse the table towards the 60.3mm diameter shoulder and rough-grind to 25.46mm thickness.	9. Use a 50mm micrometer.
10. Redress the grinding wheel if necessary and finish grind to 25.4mm plus or minus .025mm.	10. Check the left-hand traverse stop to be sure the grinding wheel will not override the shoulder of the workpiece. Use gage blocks and an electronic comparator with metric calibrations to check dimensions.
11. Clean the machine and all tools.	
12. Submit the dieholder for inspection and grade.	

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXIV *Project Name:* External Cylindrical Grinding

Job No. 1A *Job name:* Micrometer Boring Head Dial (inches) *D.O.T. No.* 603.280

Drawing No. 23.1 *Time:* $1\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Equipment:

Cutter grinder	Collet
Centering gage	Type No. 1 grinding wheel
Dial indicator	1" micrometer
Diamond dresser	Protractor
Motor-driven workhead	
Collet adapter	

Operations:
1. Wheel dressing
2. Clindrical plunge grinding
3. Bevel grinding
4. Face grinding

Materials:
Micrometer boring head dial from lathe projects

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set the worktable at zero. Set the wheelhead height properly in relation to the worktable.	1. Use a dial indicator.
2. Mount the motor-driven workhead on the worktable and swivel it to 45°.	2. Clean all parts and the worktable.
3. Attach a collet chuck to the workhead spindle.	
4. Clamp the workpiece in the chuck of a $\frac{1}{2}$" collet.	4. Use a dial indicator. The part should not exceed .0002" total indicator runout.
5. Mount a type No. 1 grinding wheel and a wheel guard.	
6. True up and dress the grinding wheel.	6. Mount the diamond dresser on the worktable.
7. Locate the grinding wheel to cover the 45° beveled area by using the crossfeed mechanism but only as a source of feed.	7. Lock the table traverse.
8. Proceed to grind the beveled area to .990" diameter by using the crossfeed.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Redress the grinding wheel if necessary. 10. Turn the workhead 90°. 11. Bring the grinding wheel into contact with the outer edge of the workpiece and traverse to the center. 12. Grind the face of the dial to finished dimension of .125". 13. Stone all sharp edges. 14. Submit the dial for inspection and grade.	11. Set the traverse stop to avoid travel of the grinding wheel over the center of the workpiece.

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXIV *Project Name:* External Cylindrical Grinding

Job No. 1B *Job name:* Micrometer Boring Head Dial (millimeters) *D.O.T. No.* 603.280

Drawing No. 23.1 *Time:* 1½ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing
2. Clindrical plunge grinding
3. Bevel grinding
4. Face grinding

Materials:
Micrometer boring head dial from lathe projects

Equipment:

Cutter grinder	Collet
Centering gage	Type No. 1 grinding wheel
Metric dial indicator	25mm micrometer
Diamond dresser	50mm micrometer
Motor-driven workhead	Protractor
Collet adapter	

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set the worktable at zero. Set the wheelhead height properly in relation to the worktable.	1. Use a metric dial indicator.
2. Mount the motor-driven workhead on the worktable and swivel it to 45°.	2. Clean all parts and the worktable.
3. Attach a collet chuck to the workhead spindle.	
4. Clamp the workpiece in the chuck of a ½" collet.	4. Use a dial indicator. The part should not exceed .0050mm total indicator runout.
5. Mount a type No. 1 grinding wheel and a wheel guard.	
6. True up and dress the grinding wheel.	6. Mount the diamond dresser on the worktable.
7. Locate the grinding wheel to cover the 45° beveled area by using the crossfeed mechanism, but only as a source of feed.	7. Lock the table traverse.
8. Proceed to grind the beveled area to 25.25mm diameter by using the crossfeed.	8. Use a 50mm micrometer.

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Redress the grinding wheel if necessary.	
10. Turn the workhead 90°.	
11. Brind the grinding wheel into contact with the outer edge of the workpiece and traverse to the center.	11. Set the traverse stop to avoid travel of the grinding wheel over the center of the workpiece.
12. Grind the face of the dial to finished dimension of 3.18mm.	12. Use a 25mm micrometer.
13. Stone all sharp edges.	
14. Submit the dial for inspection and grade.	

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXV *Project Name:* External Cylindrical Grinding

Job No. 1A *Job name:* Taper Plug Gage (inches) *D.O.T. No.* 603.280

Drawing No. 74 *Time:* 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Centerhole lapping
2. Straight wheel dressing
3. Cylindrical taper grinding (external)

Materials:
Heat-treated No. 3 Morse taper plug gage

Equipment:
Universal tool grinder
Center lap
Motor-driven workhead
R.H. tailstock and center
$\frac{1}{2}$" x 6" type No. 1 grinding wheel
Diamond dresser
Dog
Coolant system
Centering gage
No. 3 Morse ring gage
Dial indicator
1" micrometer

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select a rough-machined and heat-treated No. 3 Morse taper plug gage from stock. See illustrations on pages 78 and 82.	1. Inspect for cracks. Clean it and remove all heat-treating scale.
2. Lap the centerholes and check the centerhole angles for a 60° included angle.	2. Use a suitable 60° center lap on a drill press, lathe, or center lapping machine.
3. Place the motor-driven workhead and the right-hand tailstock on the worktable. Set the worktable properly in relation to the wheelhead.	3. Locate the workhead and the tailstock centrally on the table to minimize adjustment difficulties.
4. Lock the workhead center so it will not rotate.	4. Better accuracy is obtained using this method.
5. Mount a $\frac{1}{2}$" x 6" type No. 1 grinding wheel and dress it with a diamond.	5. Use a flood coolant when dressing and grinding.
6. Dog the work, apply center lubricant, and place it between centers.	6. Adjust for proper center tension.
7. Set the table for the proper taper and take a trial cut.	7. Convert the taper per foot to degrees as a double check. Notice the graduations at both ends of the table.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Set the trip dogs and take a trail cut. Set the work speed for 40 ft/min.	8. Set the trip dogs so that the grinding wheel passes off the end of the workpiece $\frac{1}{3}$ to $\frac{1}{2}$ the width of the wheel.
9. Proceed to grind until a suitable clean surface is obtained for gaging and sizing.	9. Use a ring gage or the local shop practice.
10. Adjust the table, if necessary, to obtain correct taper angle, and take another trial cut.	10. Repeat the process till the correct angle is obtained.
11. Measure the plug gage and note the amount of stock to be removed. Set the crossfeed dial to zero. Continue to grind to finished dimension.	11. Depth of cut should be from .0002" to .001" per traverse of the table.
12. Stop the infeed just before reaching the calculated infeed dial setting and check for size.	12. Dress the wheel if necessary.
13. Continue to grind to finish size and spark out.	
14. Make a final size check and submit for inspection and grade.	

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXV *Project Name:* External Cylindrical Grinding

Job No. 1B *Job name:* Taper Plug Gage (millimeters) *D.O.T. No.* 603.280

Drawing No. 74 *Time:* 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Centerhole lapping
2. Straight wheel dressing
3. Cylindrical taper grinding (external)

Materials:
Heat-treated No. 3 Morse taper plug gage

Equipment:

Universal tool grinder	Diamond dresser	
Center lap	Dog	
Motor-driven workhead	Coolant system	Metric dial indicator
R.H. tailstock and center	Centering gage	25mm micrometer
$\frac{1}{2}$" x 6" type No. 1 grinding wheel	No. 3 Morse ring gage	

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select a rough-machined and heat-treated No. 3 Morse taper plug gage from stock. See illustrations on pages 78 and 82.	1. Inspect for cracks. Clean it and remove all heat-treating scale.
2. Lap the centerholes and check the centerhole angles for a 60° included angle.	2. Use a suitable 60° center lap on a drill press, lathe, or center lapping machine.
3. Place the motor-driven workhead and the right-hand tailstock on the worktable. Set the worktable properly in relation to the wheelhead.	3. Locate the workhead and the tailstock centrally on the table to minimize adjustment difficulties.
4. Lock the workhead center so it will not rotate.	4. Better accuracy is obtained using this method.
5. Mount a $\frac{1}{2}$" x 6" type No. 1 grinding wheel and dress it with a diamond.	5. Use a flood coolant when dressing and grinding.
6. Dog the work, apply center lubricant, and place it between centers.	6. Adjust for proper center tension.
7. Set the table for the proper taper and take a trial cut.	7. Calculate the required taper per foot by converting metric dimensions to conventional figures. Then look up the

PROCEDURE	TECHNIQUES AND RELATED INFO.
	corresponding angle and check both ends of the table.
8. Set the trip dogs and take a trial cut. Set the work speed for 40 ft/min.	8. Set the trip dogs so that the grinding wheel passes off the end of the workpiece $\frac{1}{3}$ to $\frac{1}{2}$ the width of the wheel.
9. Proceed to grind until a suitable clean surface is obtained for gaging and sizing.	9. Use a ring gage or the local shop practice.
10. Adjust the table, if necessary, to obtain correct taper angle, and take another trial cut.	10. Repeat the process till the correct angle is obtained.
11. Measure the plug gage and note the amount of stock to be removed. Set the crossfeed dial to zero. Continue to grind to finished dimension.	11. Depth of cut should be from .006 to .025mm per traverse of the table.
12. Stop the infeed just before reaching the calculated infeed dial setting and check for size.	12. Dress the wheel if necessary.
13. Continue to grind to finish size and spark out.	
14. Make a final size check and submit for inspection and grade.	

Unit No. *Operation's job title:* Universal Tool Grinder Operator

Project XXVI *Project Name:* Internal Cylindrical Grinding

Job No. 1A *Job name:* Arbor Press Sleeve (inches) *D.O.T. No.* 603.280

Drawing No. 30.1 *Time:* 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing
2. Straight internal cylindrical grinding

Materials:
Arbor press sleeve from lathe projects

Equipment:
Universal tool grinder
Centering gage
Motorized workhead
Internal grinding head
Quill
Type No. 1 grinding wheel
Dial indicator
Diamond dresser
4-jaw independent chuck
Telescopic micrometer set

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set worktable to zero position.	1. Use a dial indicator.
2. Mount a motor-driven workhead and set it at zero. See the illustrations on the next page for general guidance.	2. Select and attach the proper pulleys to obtain 50 to 60 ft/min cutting speed.
3. Center the wheelhead and mount the internal grinding head.	3. Use the centering head provided with the machine.
4. Assemble the recommended grinding wheel and quill to the internal spindle.	4. Do not use a quill longer than necessary.
5. Attach the motor and head pulleys and adjust the belt tension.	
6. Dress the grinding wheel true and sharp.	6. Use a diamond dressing tool mounted on the worktable.
7. Clamp the workpiece in a 4-jaw chuck and true the hole.	7. Use a dial indicator and true within .001" total indicator runout. Do not apply excessive chuck jaw pressure.
8. Bring grinding wheel into contact with workpiece and zero the crossfeed dial.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Traverse the table so the grinding wheel enters the hole to the proper depth. Then set the table traverse stop.	9. Be careful not to contact the face of the chuck with the grinding wheel. One-third to one-half of the grinding wheel should be in contact with the work at the ends of the traverse.
10. Rough-grind the hole to .748" diameter.	10. Check for taper and adjust during the rough-grinding process.
11. Redress the grinding wheel if necessary.	
12. Grind to finish dimension of .750" ± .0005".	12. Check hole for bell mouthing. Use an inside telescopic micrometer.

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXVI *Project Name:* Internal Cylindrical Grinding

Job No. 1B *Job name:* Arbor Press Sleeve (millimeters) *D.O.T. No.* 603.280

Drawing No. 30.1 *Time:* 2 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Wheel dressing
2. Straight internal cylindrical grinding

Materials:
Arbor press sleeve from lathe projects

Equipment:
Universal tool grinder
Centering gage
Motorized workhead
Internal grinding head
Quill
Type No. 1 grinding wheel
Metric dial indicator
Diamond dresser
4-jaw independent chuck
Metric telescopic micrometer set

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Set worktable to zero position.	1. Use a metric dial indicator.
2. Mount a motor-driven workhead and set it at zero. See the illustrations on pages 78 and 82 for general guidance.	2. Select and attach the proper pulleys to obtain 50 to 60 ft/min cutting speed.
3. Center the wheelhead and mount the internal grinding head.	3. Use the centering head provided with the machine.
4. Assemble the recommended grinding wheel and quill to the internal spindle.	4. Do not use a quill longer than necessary.
5. Attach the motor and head pulleys and adjust the belt tension.	
6. Dress the grinding wheel true and sharp.	6. Use a diamond dressing tool mounted on the worktable.
7. Clamp the workpiece in a 4-jaw chuck and true the hole.	7. Use a dial indicator and true within .025mm total indicator runout. Do not apply excessive chuck jaw pressure. Too much pressure will distort the workpiece.

PROCEDURE	TECHNIQUES AND RELATED INFO.
8. Bring grinding wheel into contact with workpiece and zero the crossfeed dial.	
9. Traverse the table so the grinding wheel enters the hole to the proper depth. Then set the table traverse stop.	S. Be careful not to contact the face of the chuck with the grinding wheel. One-third to one-half of the grinding wheel should be in contact with the work at the ends of the traverse.
10. Rough-grind the hole to 18.95mm diameter.	10. Check for taper and adjust during the rough-grinding process.
11. Redress the grinding wheel if necessary.	
12. Grind to finish dimension of 19mm plus .0254mm, minus .000mm.	12. Check hole for bell mouthing. Use an inside telescopic micrometer.

Unit No. | *Operator's job title:* Universal Tool Grinder Operator

Project XXVII | *Project Name:* Internal Cylindrical Grinding

Job No. 1 | *Job name:* Die Wrench Body | *D.O.T. No.* 603.280

Drawing No. 7 | *Time:* $2\frac{1}{2}$ hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Internal cylindical grinding
2. Wheel dressing (diamond)
3. Table alinement

Materials:
Die wrench from lathe projects

Equipment:
Universal tool grinder
Internal grinding attachment
Centering gage
Dial indicator
Motorized workhead
Quill
Type No. 1 grinding wheel
Type No. 6 grinding wheel
Faceplate

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Anderson & Tatro. *Shop theory;* 6th edition

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Attach the internal grinding attachment to the grinding wheelhead and adjust the wheelhead to zero.	1. Clean all mating parts. See the illustrations on pages 78 and 82 for general guidance.
2. Mount a suitable grinding wheel and quill to suit the .750" dia. hole.	2. Set wheel spindle for proper surface speed.
3. Set machine worktable to zero. Adjust the wheelhead height for the proper relationship to the worktable.	3. Use a dial indicator.
4. Set up a motorized workhead at the left end of the worktable.	
5. Mount a faceplate on the workhead spindle and clamp the job to the faceplate.	5. Use strap clamps and parallels.
6. True up the 1" dia. hole.	6. Use a dial indicator.
7. Grind the $\frac{3}{4}$" dia. hole to .775".	7. Use a type No. 1 grinding wheel. Set the traverse stop to avoid hitting the faceplate with the grinding wheel.
8. Change the grinding wheel to a type No. 6 and dress it true.	

PROCEDURE	TECHNIQUES AND RELATED INFO.
9. Set traverse stop and crossfeed dial and grind to 1.015" dia. and .385" depth.	9. Use the spark contact method.
10. Grind to diameter and depth dimensions.	10. Check with vernier calipers and a vernier depth gage.
11. Remove all sharp edges. Submit the die wrench for inspection and grade.	11. Use a suitable stone.

Unit No. *Operator's job title:* Universal Tool Grinder Operator

Project XXVIII *Project Name:* Internal Cylindrical Grinding

Job No. 1A *Job name:* Taper Ring Gage (inches) *D.O.T. No.* 603.280

Drawing No. 75 *Time:* 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Internal taper grinding
2. Wheel dressing

Materials:
Heat-treated No. 3 Morse taper ring gage (rough-machined)
Brass or aluminum protection strips

Equipment:
Motor-driven workhead
Universal tool grinder
4-jaw independent chuck
Dial indicator
Internal grinding attachment
Diamond dresser
Type No. 1 grinding wheel
No. 3 Morse taper plug gage
Grinding wheel quill

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select a rough-machined and heat-treated No. 3 Morse taper ring gage from stock. Clean the scale from the exterior and the hole.	1. Inspect for cracks due to the heat-treating operations. Use a wire brush or another suitable method for removing the oxidation.
2. Adjust the workhead height in proper relationship to the worktable. See the illustrations on pages 78 and 82 for general guidance.	
3. Set up a motor-driven workhead on the left-hand end of the worktable. Mount a 4-jaw independent chuck on the spindle.	3. Be sure all bearing surfaces are clean and free of burrs.
4. Clamp the ring gage in the chuck with the large diameter facing outward. True up the hole.	4. Use a soft material between the chuck jaws and the knurl. Use a dial indicator to true the hole.
5. Set the work spindle speed for the calculated rev/min.	5. Work speed should be between 40 and 50 feet per minute.
6. Swivel the worktable to the calculated taper.	6. Cross check by using the degree and the taper-per-foot graduations.

PROCEDURE	TECHNIQUES AND RELATED INFO.
7. Mount the internal grinding attachment on the grinding wheelhead and set the head at zero.	
8. Select a suitable size of type No. 1 grinding wheel and quill, and mount them on the internal grinding attachment spindle.	8. The spindle quill should be no longer than necessary. Its diameter should be that permitted by the hole in the ring gage. The wheel diameter should be the largest that will enter the hole.
9. Select the proper spindle pulleys for the internal and workhead spindles and mount them. Attach a pulley guard.	9. Calculate the rev/min of the grinding wheel before selecting the spindle pulleys.
10. Set up a wet grinding attachment and dress the grinding wheel.	10. Dress the grinding wheel wet.
11. Bring the grinding wheel close to the wall of the ring gage and traverse the wheel the full depth of the hole.	11. Check to see if the taper setting is correct.
12. Set the table traverse stops.	12. The wheel should protrude from the hole no more than one-half its thickness.
13. Take light cuts, then check the grinding for perfect taper with a taper plug gage.	13. Use the Prussian blue method to check the taper correctness.
14. Adjust the table angle if it is not correct. Continue to grind when the taper checks out to be correct.	14. Be sure the plug gage and hole are free of all abrasive particles, chips, and dust to insure a perfect fit.
15. Continue to grind the tapered hole to final plug gage size.	
16. Submit the ring gage for inspection and grade.	

Unit No. | *Operator's job title:* Universal Tool Grinder Operator

Project XXVIII | *Project Name:* Internal Cylindrical Grinding

Job No. 1B | *Job name:* Taper Ring Gage (millimeters) | *D.O.T. No.* 603.280

Drawing No. 75 | *Time:* 4 hours

Performance Objectives:
Using only the equipment and materials listed here, the student will be able to grind the piece shown on the drawing in accordance with the time and accuracy requirements specified. After completing this job, the student will be able to complete similar jobs with like specifications.

Operations:
1. Internal taper grinding
2. Wheel dressing

Materials:
Heat-treated No. 3 Morse taper ring gage (rough-machined)
Brass or aluminum protection strips

Equipment:
Motor-driven workhead
Universal tool grinder
4-jaw independent chuck
Metric dial indicator
Internal grinding attachment
Diamond dresser
Type No. 1 grinding wheel
No. 3 Morse taper plug gage
Grinding wheel quill

Selected references:
McCarthy & Smith. *Machine tool technology;* 3d edition
Manufacturer's literature

PROCEDURE	*TECHNIQUES AND RELATED INFO.*
1. Select a rough-machined and heat-treated No. 3 Morse taper ring gage from stock. Clean the scale from the exterior and the hole.	1. Inspect for cracks due to the heat-treating operations. Use a wire brush or another suitable method for removing the oxidation.
2. Adjust the workhead height in proper relationship to the worktable. See the illustrations on pages 78 and 82 for general guidance.	
3. Set up a motor-driven workhead on the left-hand end of the worktable. Mount a 4-jaw independent chuck on the spindle.	3. Be sure all bearing surfaces are clean and free of burrs.
4. Clamp the ring gage in the chuck with the large diameter facing outward. True up the hole.	4. Use a soft material between the chuck jaws and the knurl. Use a metric dial indicator to true the hole.
5. Set the work spindle speed for the calculated rev/min.	5. Work speed should be between 40 and 50 feet per minute.
6. Swivel the worktable to the calculated taper.	6. Change the metric dimensions to conventional figures. Cross check by

PROCEDURE	TECHNIQUES AND RELATED INFO.
	using the degree and the taper-per-foot graduations on the swivel table.
7. Mount the internal grinding attachment on the grinding wheelhead and set the head at zero.	
8. Select a suitable size of type No. 1 grinding wheel and quill, and mount them on the internal grinding attachment spindle.	8. The spindle quill should be no longer than necessary. Its diameter should be that permitted by the hole in the ring gage. The wheel diameter should be the largest that will enter the hole.
9. Select the proper spindle pulleys for the internal and workhead spindles and mount them. Attach a pulley guard.	9. Calculate the rev/min of the grinding wheel before selecting the spindle pulleys.
10. Set up a wet grinding attachment and dress the grinding wheel.	10. Dress the grinding wheel wet.
11. Bring the grinding wheel close to the wall of the ring gage and traverse the wheel the full depth of the hole.	11. Check to see if the taper setting is correct.
12. Set the table traverse stops.	12. The wheel should protrude from the hole no more than one-half its thickness.
13. Take light cuts, then check the grinding for perfect taper with a taper plug gage.	13. Use the Prussian blue method to check the taper correctness.
14. Adjust the table angle if it is not correct. Continue to grind when the taper checks out to be correct.	14. Be sure the plug gage and hole are free of all abrasive particles, chips, and dust to insure a perfect fit.
15. Continue to grind the tapered hole to final plug gage size.	
16. Submit the ring gage for inspection and grade.	

Bibliography

GENERAL

Anderson, James & Tatro, Earl E. *Shop theory;* 5th ed. New York, N.Y. McGraw-Hill. 1968.

Colvin, Fred H. & Stanley, Frank A., editors. *The New American machinist's handbook.* New York, N.Y. McGraw-Hill. 1955.

Jones, Franklin D. *Machine shop training course;* 5th ed. Vol. II. New York, N.Y. Industrial Press. 1964.

Olivo, C. Thomas & Payne, Albert V. *Basic blueprint reading and sketching.* Albany, N.Y. Delmar Publishers. 1974.

METRICATION

The best references on metrication today, because many changes are taking place, are articles in magazines and newspapers. However, the following two items contain pertinent and valuable information.

Holt, Susan Frakes. "The United States and the Metric System." *Ninth District Exponent,* Dec. 1972. Federal Reserve Bank of Minneapolis. Minneapolis, Minn. 55480. (A good source of information on the metrication problem in general. Available in modest quantities without charge.)

Beloit Tool Corporation. *U.S.A. Goes Metric.* Swani Publishing Co., Box 248, Roscoe, Ill. 61073. (Contains considerable information on the technical aspects of metrication related to metalworking.)

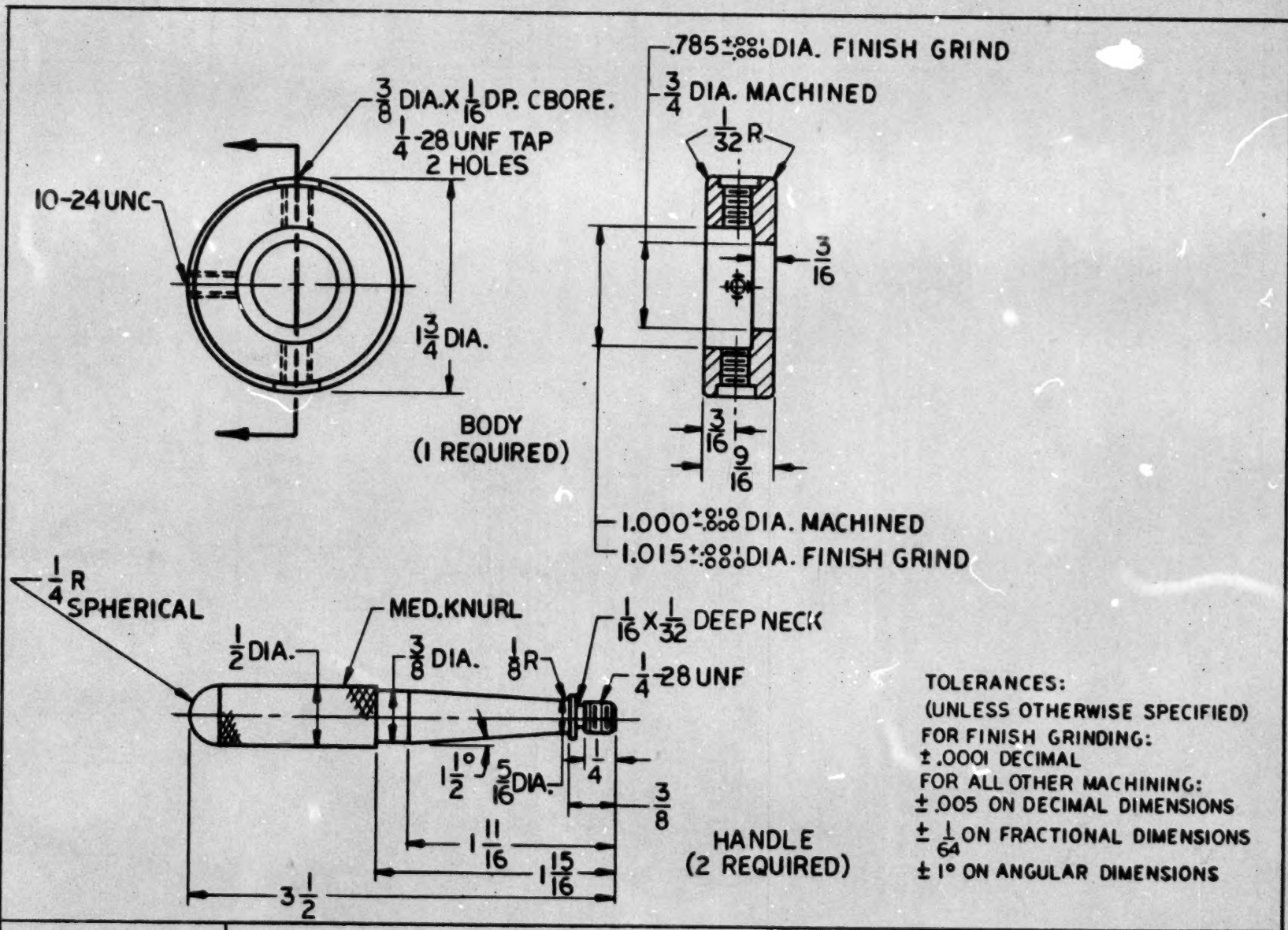
Many of the magazines and journals on vocational and technical education have articles on metrication from time to time. The April 1974 issue of *School Shop* is a special issue devoted completely to metrics. The issue as a whole is very valuable but we especially recommend the following articles in it:

"The cutting edge of metrication," by Albert B. Chalupsky and Jack J. Crawford. Page 50.
"Give 'em a centimetre and they'll take a kilometre," by James F. Snyder. Page 82.
"Metrication at Caterpillar: A talk with L.R. Strang." Page 62.

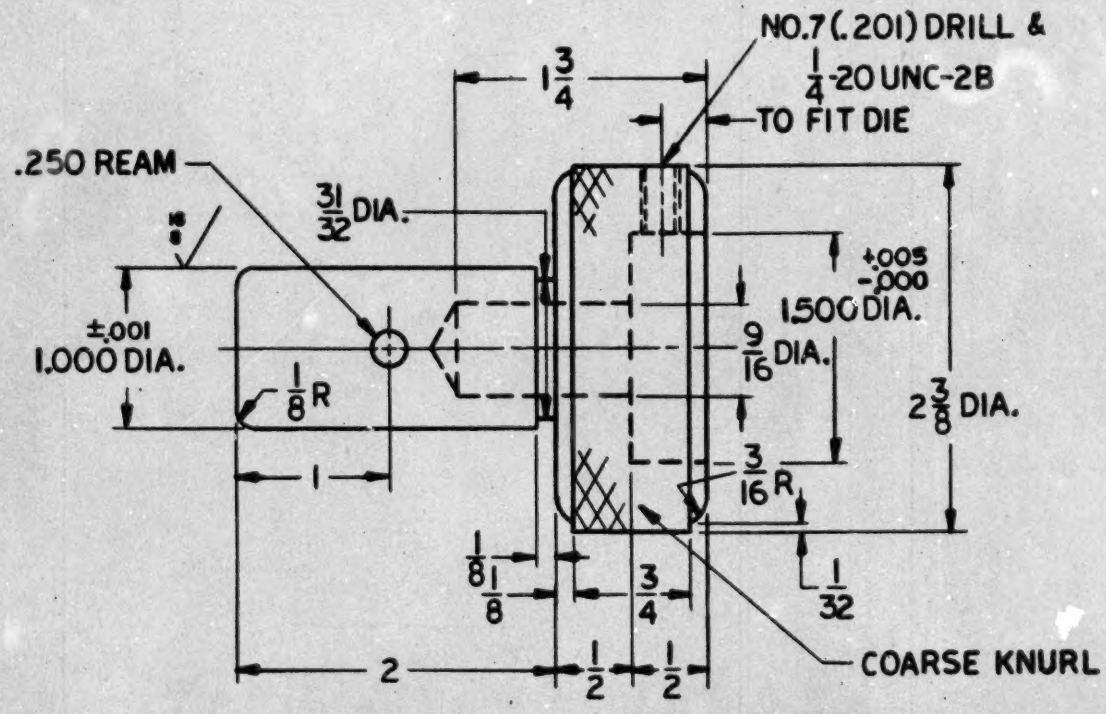
A new periodical on metrics, which began publication in 1973, is *Metric News.* It is published by Swani Publishing Co., P.O. Box 248, Roscoe Ill. 61073. Another valuable periodical is *Metric Association Newsletter* published quarterly by the Metric Association, 2004 Ash Street, Waukegan, Ill. 60085. This association also provides other publications and training aids and promotes the use of metric units in other ways.

Advertisements in the periodicals mentioned above and in others give information on tools, instruments, and training aids for metrics.

Drawings For Shop Projects



DRAWN BY: E.F.S.	DIE WRENCH	REV. 4-13-75
SCALE: ——		DWG. NO. 7



TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)

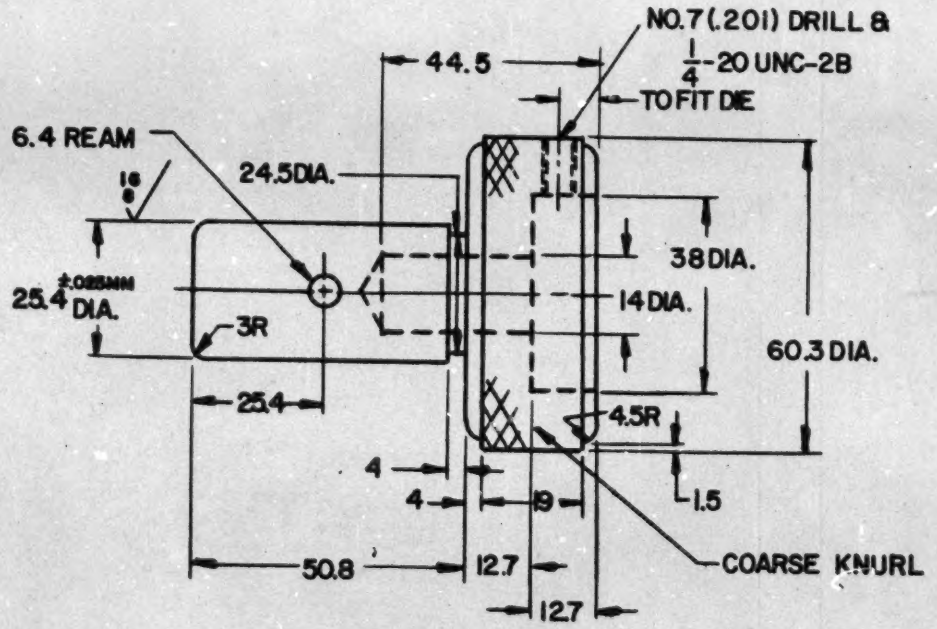
FOR FINISH GRINDING: ±.0001"

FOR ALL OTHER MACHINING:

DECIMALS: ±.005"

FRACTIONS: ±1/64"

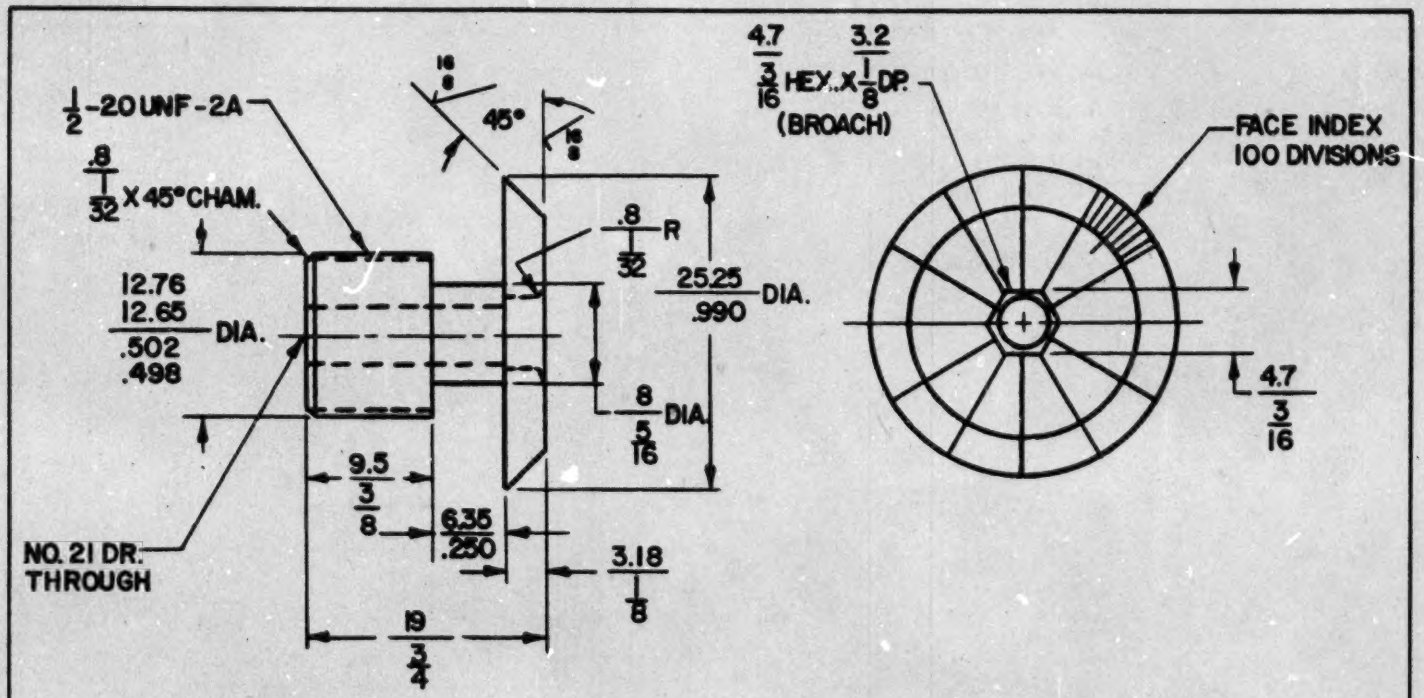
DRAWN BY: E.F.S.	LATHE DIEHOLDER	REV. 4-14-75
SCALE: ——	SLIDING HOLDER (INCHES)	DWG. NO.18A



TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)

FOR FINISH GRINDING: ±.00254
FOR ALL OTHER MACHINING: ±.127

DRAWN BY: E.F.S. SCALE: ——	LATHE DIEHOLDER SLIDING HOLDER (MILLIMETERS)	DWG. NO. 18 B



NOTES:
MATL. CRS
CASE HARDEN.

DIMENSIONING: MILLIMETER / INCH

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)

FOR FINISH GRINDING:
± .0001" DECIMAL ± .00254 MM
FOR ALL OTHER MACHINING:
± .005" DECIMAL ± .127 MM
± 1/64" FRACTIONAL ± .4 MM

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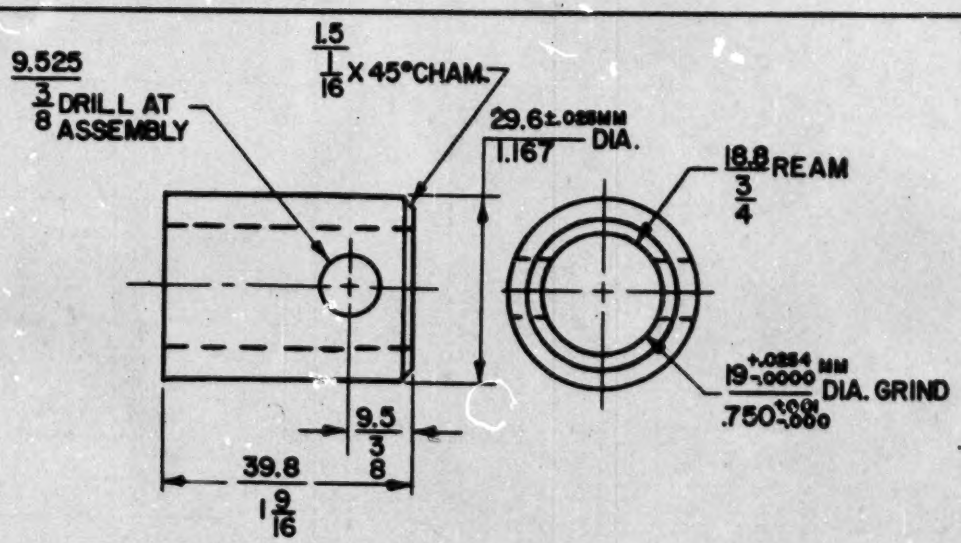
SCALE: ——	DIAL (DUAL DIMENSIONING)	DWG. NO. 23.1



NOTES:

MATL. C1010

1 REQD.

GRIND TO SPECIFIED TOLERANCE.

DIMENSIONING: MILLIMETER / INCH

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)

FOR FINISH GRINDING:
±.0001" DECIMAL ±.00254 MM

FOR ALL OTHER MACHINING:
±.005" DECIMAL ±.127 MM
± 1/64" FRACTIONAL ±.4 MM

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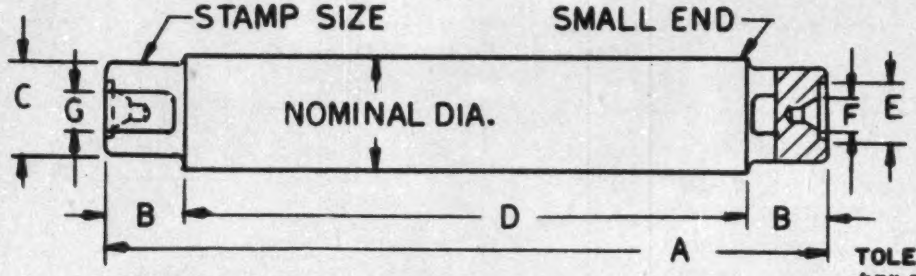
SCALE: ——	SLEEVE (DUAL DIMENSIONING)	DWG. NO. 30.1

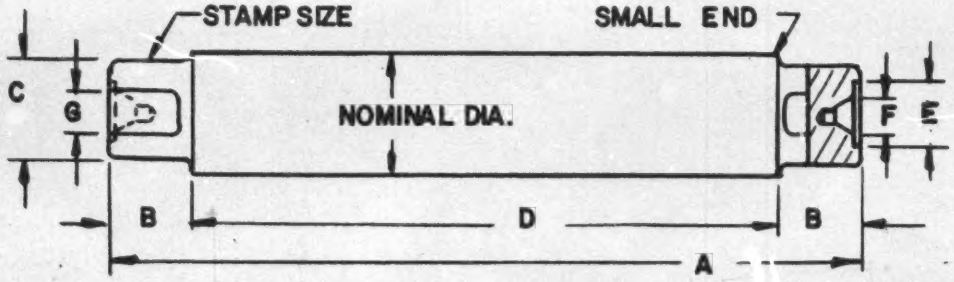


TAPER PER INCH .0005
DIAMETER OF SMALL END TO BE .0005 BELOW NOMINAL DIAMETER.
ALLOW .025 ON NOMINAL DIA. FOR GRINDING.

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FOR FINISH GRINDING: ±.0001"
FOR ALL OTHER MACHINING:
DECIMALS: ±.005"
FRACTIONS: $\pm\frac{1}{64}$"

JOB NO.	NOMINAL DIA.	A	B	C	D	E	F	G
1	3/16	3 5/8	5/8	5/32	2 5/8		5/64	1/8
2	1/4	3 7/8		7/32	2 7/8	11/64	1/8	5/32
3	5/16	4 1/8		9/32	3 1/8	7/32	5/32	3/16
4	3/8	4 1/4		11/32	3 1/4	1/4	7/32	7/32
5	7/16	4 1/2		13/32	3 1/2	1/4	7/32	1/4
6	1/2	5 1/8	5/8	15/32	3 7/8	5/16	7/32	1/4
7	9/16	5 3/8		17/32	4 1/8	5/16	7/32	9/32
8	5/8	5 1/2		19/32	4 1/4	17/32	1/4	9/32
9	11/16	6	3/4	21/32	4 1/2	3/8	1/4	5/16
10	3/4	6 1/8		23/32	4 5/8	7/16	1/4	5/16
11	13/16	6 1/4		25/32	4 3/4	13/32	5/16	5/16
12	7/8	6 3/8		27/32	4 7/8	17/32	5/16	3/8
13	15/16	6 1/2		29/32	5	9/16	5/16	3/8
14	1	7	7/8	31/32	5 1/4	9/16	5/16	3/8
15	1 1/2	7 1/4		1 1/16	5 1/2	9/16	5/16	3/8
16	1 1/4	7 1/2		1 3/16	5 3/4	5/8	3/8	7/16

DRAWN BY: E.F.S.	LATHE MANDREL (INCHES)	REV. 4-11-75
SCALE: ——		DWG. NO. 34A



TAPER PER 25MM = 0.012 MM
DIAMETER OF SMALL END TO BE 0.012 BELOW NOMINAL DIAMETER.
ALLOW 0.600 ON NOMINAL DIAMETER FOR GRINDING.

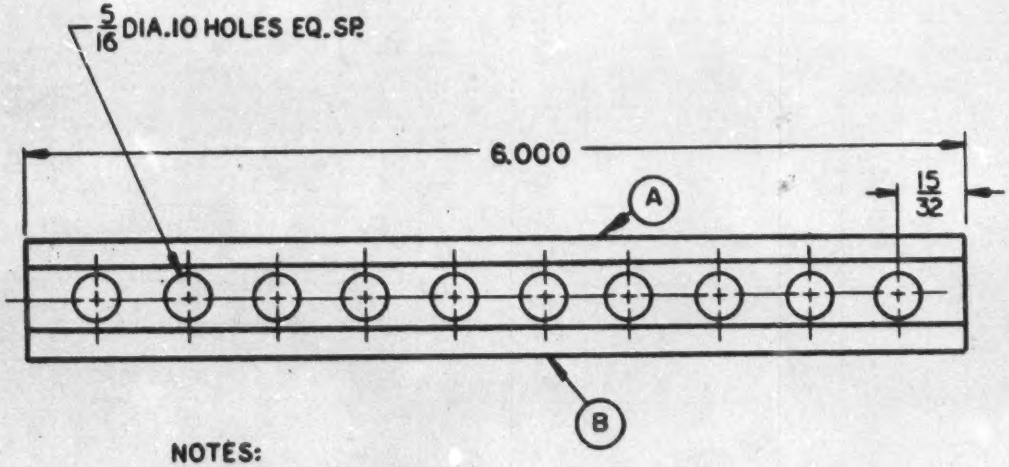
JOB NO.	NOMINAL DIA.	A	B	C	D	E	F	G
1	5	92	15.8	4	60.4	3.5	2	3
2	6	98		5.0	66.4	4.5	3	4
3	8	102		7	70.4	5.5	4	4.5
4	9.5	108		8.5	76.4	6.5	5.5	5.5
5	11	114		10.0	82.4	6.5	5.5	6
6	12.5	130	15.8	11.5	98.4	8	5.5	6.5
7	14	136		13.0	104.4	8	5.5	7
8	16	140		15	108.4	8.5	6.5	7
9	17.5	152	19	16.5	114	9.5	6.5	8
10	19	155		18	117	11	6.5	8
11	20.5	159		19.5	121	10.5	8	8
12	22	162		21	124	13.5	8	9.5
13	24	166		23	128	14	8	9.5
14	25.5	178	22	24.5	134	14.5	8	9.5
15	32	181		30	137	14.5	8	9.5
16	38	190.5		36	146.5	16	9.5	11

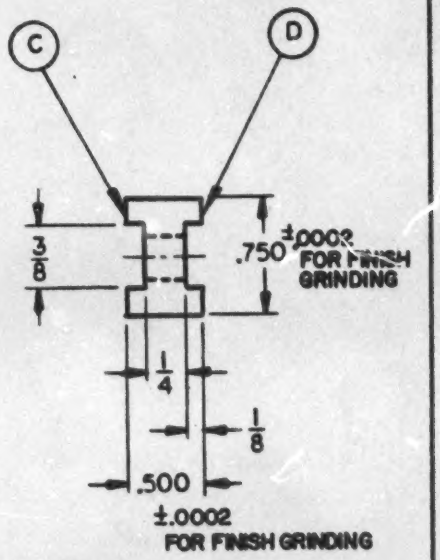
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FOR FINISH GRINDING: ± .00254
FOR ALL OTHER MACHINING: ±.127

DRAWN BY: E.F.S.
SCALE: —

LATHE MANDREL (MILLIMETERS)

DWG. NO. 34B





NOTES:
MATL. C R S SAE 1020
BREAK ALL SHARP EDGES.
HARDEN AND TEMPER, FINISH GRIND TO 16 MICROINCHES.
2 REQD. (MATCHED IN PAIRS)
LEAVE .030 FOR GRINDING ON .500, .750 AND 6.000 DIMENSIONS.

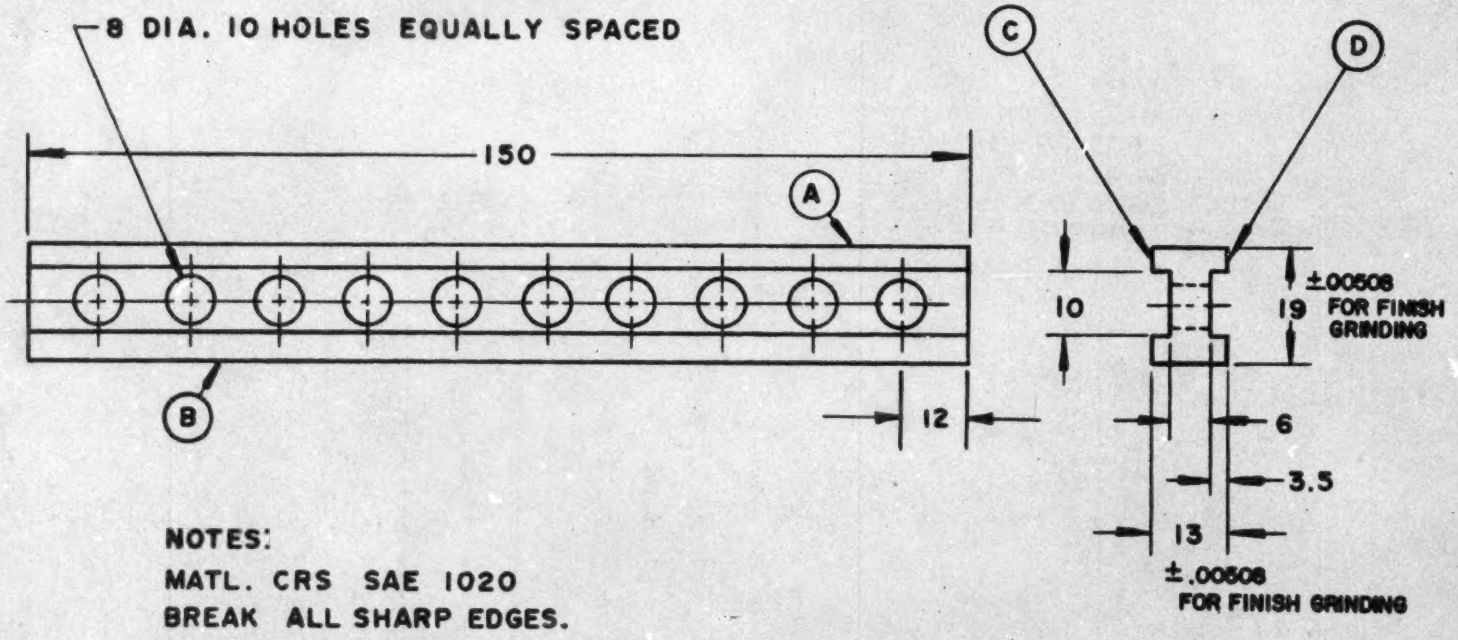
TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)

FOR FINISH GRINDING AND OTHER MACHINING:

DECIMALS: ±.005"

FRACTIONS: ± 1/64"

DRAWN BY: E.F.S.	PARALLELS (INCHES)	REV. 4-12-75
SCALE: ——		DWG.NO. 50 A



NOTES:

MATL. CRS SAE 1020

BREAK ALL SHARP EDGES.

HARDEN AND TEMPER. FINISH GRIND TO 16 MICROINCHES.

2 REQD. (MATCHED IN PAIRS)

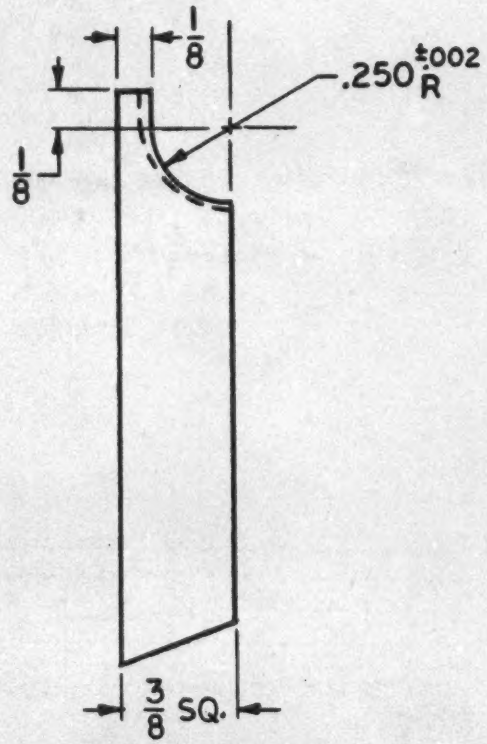
LEAVE .7620 FOR GRINDING ON 13, 19, AND 150 DIMENSIONS.

TOLERANCES:

(UNLESS OTHERWISE SPECIFIED)

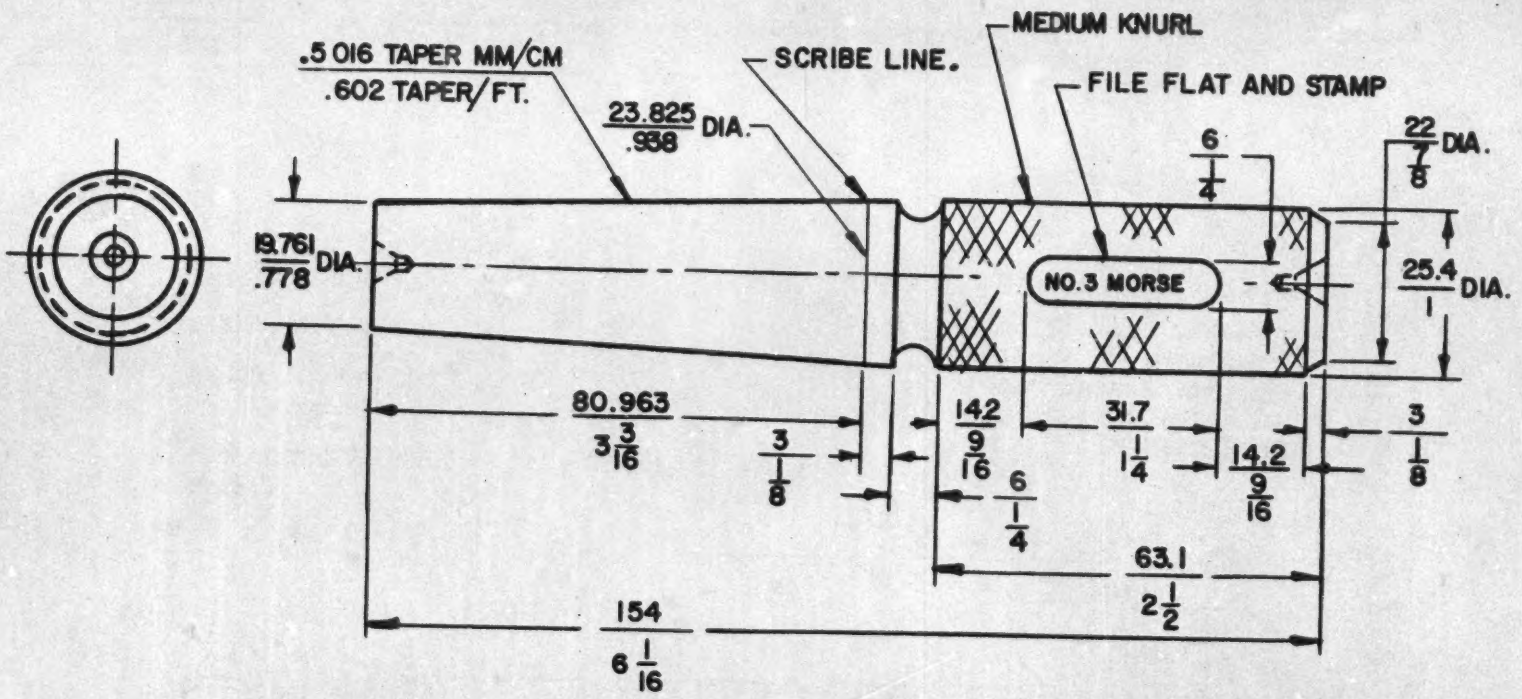
FOR FINISH GRINDING AND OTHER MACHINING: ±.1270

DRAWN BY: V.C.L.	PARALLELS (MILLIMETERS)	REV. 4-12-75
SCALE: ——		DWG.NO. 50 B



TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FOR FINISH GRINDING: ± .0001"
FOR ALL OTHER MACHINING:
DECIMALS: ± .005"
FRACTIONS: ± 1/64"

DRAWN BY: E.F.S. SCALE: ——	LATHE FORMING TOOL FOR DIE WRENCH HANDLE	DWG. NO. 73



NOTES:

NO.3 MORSE STD. TAPER TEST PLUG

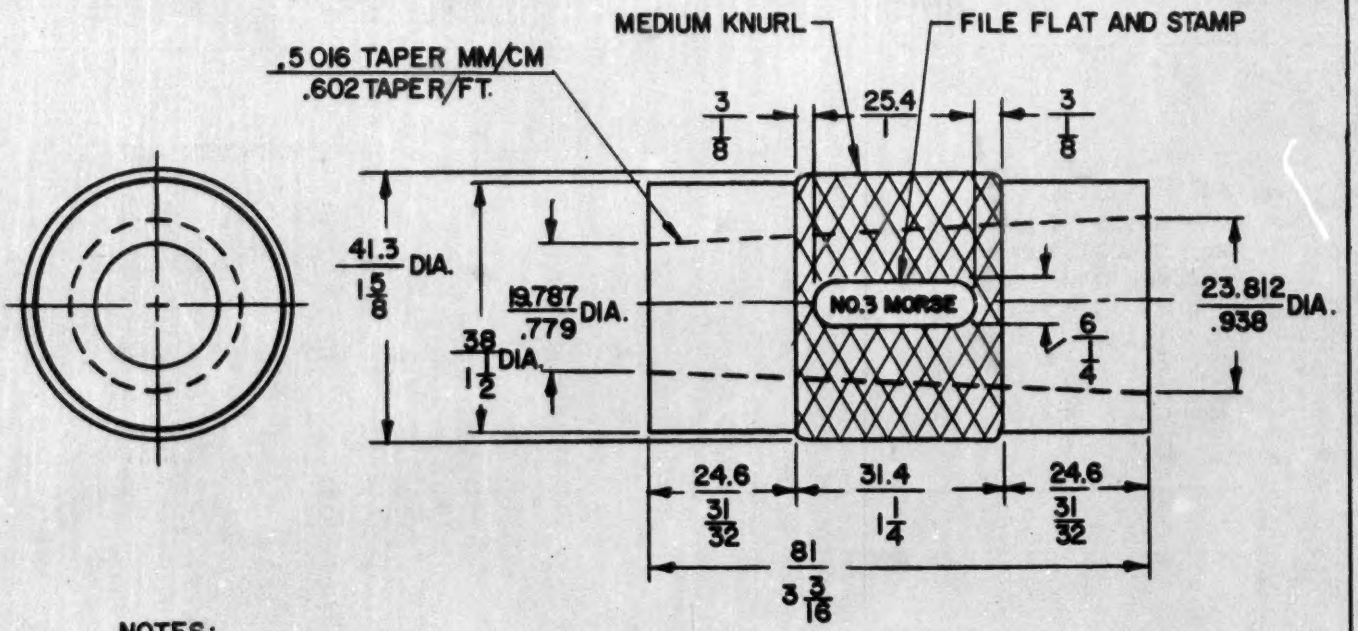
STOCK: 27/1 1/16 DIA. X 155.5/6 1/8 LONG

FINISH ALL OVER.

DIMENSIONING: MILLIMETER / INCH

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FOR FINISH GRINDING:
±.0001" DECIMAL ± .00254 MM
FOR ALL OTHER MACHINING:
± .005" DECIMAL ±.127 MM
± 1/64" FRACTIONAL ±.4 MM

DRAWN BY: E.F.S.	TAPER PLUG GAGE (DUAL DIMENSIONING)	
SCALE: ——		DWG.NO. 74



NOTES:
NO.3 MORSE STD.TAPER TEST SOCKET

STOCK: $\frac{44.5}{1\frac{3}{4}}$ DIA. X $\frac{82.6}{3\frac{1}{4}}$ LONG

FINISH ALL OVER.

DIMENSIONING: MILLIMETER / INCH

TOLERANCES:
(UNLESS OTHERWISE SPECIFIED)
FOR FINISH GRINDING:
±.0001" DECIMAL ± .00254 MM
FOR ALL OTHER MACHINING:
±.005" DECIMAL ± .127 MM
± 1/64" FRACTIONAL ± .4 MM

DRAWN BY: E.F.S.	TAPER RING GAGE (DUAL DIMENSIONING)	
SCALE: ——		DWG. NO. 75